BOOK OF ABSTRACTS

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CERAMICS AND COMPOSITES

Microstructure control in ceramics by colloidal processing and magnetic field

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Microstructure control in ceramics is important and effective for improving their properties.We focus on crystallographic orientation as a parameter of microstructure control as well as grain size, grain boundary, second phase, etc.Since the agglomeration of particles forms large residual pores in green bodiesusing the conventional processing, elevated temperatures are necessary for densification. Colloidal processing is an effective technique for controlling the pore size distribution in green compacts before sintering, anda strong magnetic field can be used for controlling the orientation even in diamagnetic ceramics. A commercially available SiC (6H) powder with the average particle size of 0.55 μm was used as the starting materials.Aqueous suspensions with dispersed particles were prepared by adjusting pH and consolidated by slip casting in a strong magnetic field to prepare the dense green compactswith orientation.The green compacts without sintering additives were densified by SPS in avacuum atmosphere. When using the dry processing for consolidation, the density of the sample sintered by SPS in a vacuum atmosphere at 1950℃ was 92% of the theoretical value. When the green compact prepared by slip casting was sintered by hot pressing, the density was 78%. However, the density of SiC sintered by SPS increased with the increasing sintering temperature and the relative density of SiC prepared by SPS was more than 97% at the sintering temperature of 1950℃.When the slurry was consolidated by slip casting in a strong magnetic field, the c-axis in SiC(6H) was aligned parallel to the magnetic fieldafter sintering. From EBSD analysis, approximate 88% of the grains were aligned with a tilt anglebetween the c-axis and the magnetic field direction less than 20°.The thermal conductivity and electric conductivity perpendicular to the c-axis were higher than those parallel to the c-axis. Even when Al2O3 andY2O3are used as the sintering additives, the crystallographic orientation can be controlled, andhot pressing can be used for densification.The 3-point bending strengths were 907and 799 MPa for the crack-growth directions parallel andperpendicular to the c-axis in the textured SiC, respectively,and for the random SiC, the strength was 724 MPa. We can apply this technique to the wide variety of ceramics without cubic crystal structure, evenif they possess paramagnetic and diamagnetic properties.

Microstructure and properties of silicon infiltrated diamond-SiC composites

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Silicon carbide bonded diamond composites are one class of materials with very high potential for a wide range of challenging applications in the industry. The mechanical properties of very high hardness and wear resistance as well as the high thermal conductivity meet the requirements for components of modern industrial plants. Diamond-SiC composites prepared by Silicon infiltration of diamond preforms provide lower diamond contents in comparison to HPHT diamond composites.However, they can produced without high pressure and in different sizes and geometries. The mechanisms of the formation of the microstructure of these materials will be explained. Additionally, the correlation of the properties of the materials with the microstructure will be discussed. These materials are unique materials with high thermal conductivity (600 W/mK) and excellent abrasive wear resistance. The materials show coefficients of friction and a wear behavior under tribological load corresponding to those of CVD-diamond coatings.

The Samsonov Configurational Model: Instructive Historical Remarks And The Extension Of Its Application To New Problematics

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G. V. Samsonov left an enormous legacy in materials science, even though a large portion of his and his group's work has remained virtually unknownto the western world. One of his crowning theoretical contributions that received some level of recognition in the west was the configurational model of the solid state based on the statistical weight of atoms with stable configuration (SWASC). However, only a handful of papers employing this model were published in the western journals since the model was developed, in 1965. In this lecture, I will argue in favor of the necessity for a broader implementation of this model to address various empirical problems in materials science. I will illustrate this argument with the attempt to apply the configurational model to explain specific chemical properties of oxide ceramics doped with transition elements. It will be shown that the model proves satisfactory in explaining the effects of divalent transition elements on solubility of hydroxyapatite. Namely, SWASC values for half-filled d orbitals of transition elements in the ± 5 pm range of ionic radii centered around iron correlate monotonously with the solubility change. Here, Samsonov'sconfiguration model is being revived through a new application. With the dissemination of this model applied to new problems in materials science, it is hoped that the interest in the work of G. V. Samsonovand the generation of his scientific contemporaries from the Kiev school of advanced materials would get revived as well.

Influence Of CIP Before Sintering Of Powder Workpieces Of Composition WC-8Co-0.3VC On The WC Grain Size In Cemented Carbide After Sintering In Vacuum

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In this work, the combined effect of 200 MPa CIP before sintering and VC grain growth inhibitor addition on the WC grain size after sintering of WC-8Co-0.3VC cemented carbide were investigated. The compacted blanks were divided into two groups. Subsequently, one was put into elastic mold and densified by cold isostatic pressing (CIP). Sintering was carried out in a vacuum sintering furnace. The microstructure observation of the alloys was studied using scanning electron microscopy (SEM). The TRS was determined using three-point bend test according to the standard of ISO3327:2009. It is shown that applying CIP before sintering decreases the WC mean grain size and increases the TRS of sintered samples. The WC mean grain size of the VC-containing unCIP-ed WC–8Co alloy is 0.80 µm. After applying CIP, that for the same alloy is decreased to 0,68 µm. Moreover, the CIP-ed alloy has a highest TRS value of 1220 MPa, which is higher that the value of 1200 MPa for the unCIP-ed alloy. At the same time, for comparison, a similar study was carried out on samples without VC. It is shown that the CIP-ed alloy has finer WC grains with an average value of 0.84 µm, and has the lowest TRS value of 1590 MPa. For the alloy that did not pass CIP, the WC mean grain size and TRS change into 0.88 µm and 1650 MPa, respectively. Thus, for the first time, it was found that the combined action of VC addition and CIP plays a great inhibiting effect on the grain growth of WC and leads to submicron-grained microstructure, as well as the decrease in TRS of alloys. The explanation of the obtained effects is based on the synthesis of the results and discussions given in [1], where it was shown how and why the preliminary CIP of sample blanks with a pressure of 200 MPa contributes to a decrease in the WC grain size during sintering of WC-Co cemented carbide and in [2], where it was explained how VC addition restricts grain growth during liquid-phase sintering.

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Methods Of Layer-By-Layer Synthesis Of Ceramic Filters With Channels Of Given Geometry

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To obtain high-quality metal castings it is important to filter the melt in a mold. Pressed ceramic and foam ceramic filters are usually used for these purposes. The disadvantages of such filters are low filtration capacity. The latter can be increased by creating channels in the filter of a given geometry, which would help to effectively retain harmful inclusions and not reduce the bandwidth of the filter. The use of the Binder Jetting method due to its high cost is unacceptable. We have developed methods for forming filters, which include the application of ceramic layers and alternate 3D printing of pores from fusible material. The flat-bottomed ceramic frame automatically goes back and forth on the shuttle platform: under the hopper to fill the ceramic layer and spray it with activator, and then under the print head of the FDM printer, which applies a mesh of pores to each ceramic layer. The printing of mesh or cellular pore channels allows to optimize their design in terms of filtering capacity, hydraulic resistance, pore surface area and such geometrical indicators that allow to best capture harmful particles from metal melts in the filter webs. Filters can be made of ceramic materials such as alumina, mullite or silica. Pores can be printed with PLA, PVA, HIPS or other types of plastic that are easily removed by dissolving or burning. The use of affordable FDM printing at low cost allows you to create ceramic filters that effectively clean the metal melt and do not significantly increase the final cost of castings. In addition, the advantage of this method of manufacturing ceramic filters over the traditional method using reticulated polyurethane foam is the absence of small ceramic particles that can be washed away by the melt and get into the casting.

Multicomponent Ceramic Composite B4C–TiB2–W2B5–Co Formation Process From Available Compounds By Wet Method

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Boron carbide (B4C) has unique physical-chemical properties, but is characterized with relatively low strength and fracture toughness complicating the products fabrication. It is confirmed that tungsten carbide–cobalt (WC–Co) composite additive increases the boron carbide matrix ceramics sinterability. Introducing of tungsten and titanium borides, W2B5 and TiB2, also increase its sinterability. This work aims obtaining of new technologies for production of boron carbide based matrix ceramic B4C–TiB2–W2B5–Co from commercially available compounds by wet method [1–4]. Target composite can be obtained by sintering a mixture of commercial powders of components (B4C, TiB2, W2B5, Co). The size of ceramic primary crystals depends on the initial particle size, which increase at high-temperature (>1600°C) sintering. With the proposed method it is possible to obtain of multicomponent composite with grain sizes of 400–1000 nm. A viscous paste is obtained from amorphous boron–titanium tetraisopropoxide–ammonium paratungstate–sucrose–cobalt acetate mixture pyrolysis at 200–600°C. During preceramic precursors annealing at 800–1200°C the following chemical processes take place: carbothermal reduction of cobalt and tungsten oxides at >700°C; obtaining of WC–Co composite at 700–1000°C; formation of titanium carbide TiC phase at 1000–1200°C and its transformation into TiB2 at >1200°C; formation of B4C phase at >1000°C; and partial formation of W2B5 phase at 1000°C. Above 1300°C WC transforms into W2B5 phase. It is established that without cobalt at 1000°C no W2B5 phase formation occurs. The obtained ceramic composition powders are sintered at 1500–1800°C (50 MPa, 10 min) by SPS method. The grain sizes of B4C–TiB2–W2B5–Co ceramic samples are in the range of 0.5–2.0 μm. It can be concluded that cobalt and tungsten compounds are effective grain size growth inhibitors in multicomponent boron carbide matrix ceramics.

Acknowledgments

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Phase Compatibility Of AlFeCoNiCrTi/WC-W2C Prepared Via SPS

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The modern metalworking industry cannot develop and improve the quality of products without creating fundamentally new cutting materials. Such materials should increase service life (more than 100 h) and retain mechanical properties at elevated temperatures. In this regard, the most promising is the replacement of the traditional cobalt matrix with a high-entropy alloy (HEA). It is worth using carbides as refractory inclusion, particularly WC-W2C. Compatibility factors (thermodynamic, kinetic and thermomechanical) are critical when building composite materials. The thermodynamic compatibility of the WC-W2C/10 wt.% AlFeCoNiCrTi composite was evaluated by the SPS method at temperatures of 1200–1500°C. It is shown that after sintering at 1200–1300°C, a reaction-diffusion layer of the phase (Fe, Co, Ni, Cr)xWyCz is formed. An increase in temperature up to 1400–1500 °C (Fe, Co, Ni, Cr)xWyCz carbide is also saturated with titanium atoms forming Fe, Co, Ni, Cr, Ti)xWyCz. Kinetic compatibility was evaluated during annealing in a vacuum furnace at 1100 °C for 30, 60, and 120 min. The limited solubility and time-controlled diffusion processes indicate the thermodynamic and kinetic compatibilities of the phases in composite WC-W2C/10 wt.% AlFeCoNiCrTi. However, in the liquid-phase process mode, there is no control over the process of chemical interaction between the components, which casts doubt on their thermodynamic compatibility. The thermo-mechanical compatibility was evaluated by measuring the CTE of AlFeCoNiCrTi and WC-W2C, which was found to be 12 × 10-6 K-1 and ~ 9.5 × 10-6 K-1, respectively. In terms of thermomechanical compatibility, the CTE of the matrix phase is slightly higher than that of the ceramic one. However, the observed difference does not exceed 2.5 × 10-6 K-1, which suggests sufficient thermomechanical compatibility of the phases.

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Optimization Of Rheological Properties Of High Solid Loading Suspensions For Obtaining Y_2O_3 IR-Transparent Ceramics

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Y_2O_3 ceramics is an important IR-transparent material due to their chemical stability, high melting point (2430°C), wide transparency range (0.2-8 μm), thermal and corrosion resistance [1]. Slip casting followed by vacuum sintering allows to produce high-quality complex geometry ceramic samples with smaller grain sizes and fewer macro defects as a result of the uniform particle distribution [2]. However, this approach requires stable suspensions with high solid loading exhibiting Newtonian fluids behavior. Fabrication of such slips is a difficult task because high surface area of powders increases the viscosity or even causes instability of suspensions due to agglomeration. This work aims to optimize Y_2O_3 slips for IR-transparent ceramics with complex geometry. The effects of dispersant type (NH_4PAA and Dolapix CE64) and their concentration on the stability of Y_2O_3 nanopowders suspensions were investigated. Dolapix CE64 is more effective for obtaining stable suspensions due to its lower molecular weight than NH_4PAA. The rheological properties of Y_2O_3 highly-loaded aqueous suspensions were studied. 30 wt% Y_2O_3 and 1.5 wt% Dolapix CE64 suspension behaves like Newtonian fluid. 32.5 and 35 wt% Y_2O_3 suspensions exhibited pseudoplastic properties due to agglomerates formation. Hemispherical ceramics were cast using optimized suspensions and sintered in a vacuum at 1750°C. The samples have a density close to the theoretical (5.23 g/cm^3) and a homogeneous grain structure with a grain size of 10-15 μm. The samples' microhardness 9.3 GPa was comparable to that of Y_2O_3 ceramics consolidated by cold isostatic pressing and vacuum sintering. The transmittance of obtained ceramics reaches 63% at 2000 nm.

Acknowledgments

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Microstructure And Optical Properties Of Y3Al5O12:Sm3+ (3-15 At.%) Transparent Ceramics

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Diode-pumped Q-switched YAG:Nd3+ laser media find various applications in medicine, scientific research, defense, etc. However, the optical conversion efficiency of such lasers is constrained by the quantum defect, absorption of the pump light, and amplified spontaneous emission. In order to increase the conversion efficiency of lasers we need to suppress parasitic oscillations and amplified spontaneous emission by utilizing the layer claddings on the gain medium. YAG:Sm3+ is an optimal suppressor of parasitic oscillations of YAG:Nd3+ laser due to combination of its optical properties. However, the effect of Sm3+ ions concentration on the preparation and properties of YAG:Sm3+ ceramics has not been described in the modern literature. The aim of this work was to establish the effect of samarium ion concentration on the microstructure and optical properties of YAG:Sm3+ ceramics. The effect of Sm3+ ion concentration on the structural-phase state and optical properties of transparent YAG: Sm3+ ceramics obtained by reactive sintering in vacuum at 1725°C was studied for the first time. High-quality ceramic samples with high optical transparency were produced within the concentration range studied. It was found that with increasing concentration of Sm3+ ions from 3 to 15 at.% the average grain size of ceramics slightly decreases from 24 to 18 μm. XRD data shows that single-phase YAG is formed within the concentration range studied. At the same time, for YAG:Sm3+ ceramics doped with 11 and 15 at.% of samarium ions, impurity phases of uncertain composition are observed by FESEM method, resulting in increase the optical losses of ceramics at 808 nm. Thus, the solubility limit of Sm3+ ions in the crystalline structure of garnet lies in the 9-11 at.%. concentration range. The optical absorption coefficient of YAG:Sm3+ (3-15 at.%) at 1064 nm increases linearly with increasing concentration of Sm3+ ions, and reaches 8 cm-1 for the concentration of 15 at.%.

High-Temperature Ceramics Reinforced With High-Entropy Borides

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Materials based on boron carbide are increasingly used in industry due to its unique complex of physical and mechanical properties. One of the most effective ways to improve the strength of the ceramics is a fiber reinforcement, which is realized in the directional solidification of eutectic alloys. In recent years, high-entropy borides have attracted considerable interest due to their potential applications as high-temperature structural materials. In this work authors used high-entropy borides as the reinforced phase during directional solidification of eutectic alloys based on boron carbide. The directionally solidified B4C-based ceramics (B4C-(Ti,Zr,Hf,Nb,Ta)B2, B4C-(TixZr1-x)B2) were prepared by the floating zone method based on the crucible-free zone melting of compacted powders. B4C and powders of transitional metals diborides (TiB2, ZrB2, HfB2, TaB2 and Nb B2) with technical purity were used as the initial materials. The microstructure of all as prepared alloys consists of B4C matrix uniformly reinforced by single phase diboride fibers and lamellas. The formation of eutectic structure, phase compositions and mechanical properties of the directionally solidified composites were discussed.

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Physics Of Processes For High-Speed Consolidation Of Powders Of Refractory Compounds, Metals And Alloys

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More than 500 compounds were synthesized by Samsonov and his team. Sintered materials were usually used to study the properties. As purity of as-prepared refractory compound was decreased, the new methods for consolidation should be developed. For the last 40 years the Department of High-temperature Materials and Powder Metallurgy has created fundamentally new technologies for production of single crystals and composites based on refractory compounds: zone melting of powder materials with moving solvent; sintering in the field of temperature gradient of capillary porous bodies, with moving solvent; selective hot pressing in conditions of local electron-beam and induction heating. All these methods allow to obtain compact materials based on refractory compounds with purity up to 99.99%. The feature of these processes is that the powder sample is heated in a field of temperature gradient greater than 1000 deg/cm and moves at a speed of 1-10 mm/min. The study of the kinetics of the sintering process revealed that the densification rate for samples with porosity of 40-45% to non-porous state is less than 60 seconds. Analysis of stresses occurring in samples under conditions of temperature gradient shows that they are less than the strength of the samples. It is proved that compression stresses less than 60 MPa are formed in the samples during sintering in regions with width less than 200 μm. Compression stresses are added to the stresses caused by surface tension forces and intensify the densification process. The mechanism is confirmed by fact that the nature of a powder material has less effect on densification rate than the magnitude of compression stresses. Thus, the processes of rapid consolidation of powder samples based on refractory compounds, metals and alloys in the field of temperature gradient can be the basis for the creation of breakthrough high-performance technologies for the production of new classes of functional materials with high purity.

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New Insight In High-Temperature Interfacial Chemical Reactivity Test Of Steel And Glass-Ceramics

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Glass-ceramic and steel interfaces are common in solid oxide cell technologies. The high-temperature interactions between steel and glass-ceramic are critical in degradation properties matter. Therefore fundamental understanding of the interaction between different elements of the cell – as chemical interaction between glass-ceramic and metallic interconnect is essential for obtaining good adhesion. The present study exploit large surface-to-volume ratio of steel powder particles. The use of metallic particles instead of dense steels in the joining with glass-ceramic materials allowed to accelerate the observation of chemical reactivity between them. The reactivity of three different glass-ceramics materials • Na-containing (46.37 wt.% SiO2, 14.34 wt.% CaO, 8.34 wt.% Al2O3, 2.96 wt.% ZrO2, 5.76 wt.% B2O3, 9.26 wt.% Na2O, 13 wt.% MgO) • Ba-containing (57.6 wt.% SiO2, 6.17 wt.% Al2O3, 5.65 wt.% B2O3, 28.84 wt.% SrO, 1.74 wt.% Y2O3) • Sr-containing (55 wt.% SiO2, 7 wt.% CaO, 4 wt.% Al2O3, 8 wt.% B2O3, 26 wt.% BaO) in contact with Fe22Cr stainless steel powders (raw and pre-oxidised) were investigated. Detailed glass-ceramic chemical compositions are shown in the table below. Samples were exanimated at 750°C and 850°C for 500 hours in static air. Furthermore, post-mortem analysis was carried out using scanning electron microscopy (SEM), energy dispersive X-ray analysis (EDS), X-ray diffractomery (XRD) and X-ray photoelectron spectroscopy (XPS). The present research explores, for the first time, the effects of exposing the high surface area of the alloy powder and glass-ceramic interface, assessed by oxidation testing and microstructural analysis. Due to the powder nature of the materials, it was possible to perform XRD and XPS analyses, which are typically problematic for planar interfaces. The results were consistent and allowed for a better observation and understanding of the chemical reactivity processes. The experiments showed that Sr-containing samples are more stable and less chemically reactive compared to the Ba-containing materials.

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Phase Relation Studies In The ZrO2–HfO2–Nd2O3 System At 1500°C

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The development of technology and industry requires the creation of new ceramic materials with improved properties. Ceramic materials based on zirconium dioxide and hafnium doped with rare earth elements (REE) oxides are promising for the creation of new materials functional and structural purpose. Partially or completely stabilized zirconium dioxide is used as a functional and structural ceramic due to its unique combination of physical and mechanical characteristics. Present work is about phase equilibria in the ternary ZrO2–HfO2–Nd2O3 system at 1500 ℃ in air in the whole concentration range. X-ray diffraction and electron microprobe X-ray diffraction were used to determine phase contents. The microstructures of the sintered and melted ceramic samples were examined by using the scanning electron microscopy (SEM). The X-ray analysis of the samples was performed by powder method using DRON-3 at room temperature (CuKα radiation) with step size of 0.05–0.1 degrees in the range 2θ = 15–90°. The phase equilibria in the ternary system ZrO2–HfO2–Nd2O3were studied and an isothermal section at 1500 ºC was constructed. The formation of new phases in the studied system was not observed. It is established that at the research temperature in this system continuous rows of cubic solids with a structure of fluorite and pyrochlore-type are formed. The structure of the isothermal section of the ternary phase diagram of the ZrO2–HfO2–Nd2O3 system at 1500 ºC is characterized by the formation of three three-phase regions (A + F + Py, F+Py+T, (M+T+Py) and eight two-phase regions (A+F, Py+A, two F+Py, F+T, Py+T, T+M, Py+M). The obtained results can be used to create new ceramic materials for functional and structural purposes with predetermined properties.

Carbon Nanostructures As Fillers Of Solid Polymers That Increase The Characteristics Of A Composite Adapted For 3D Printing (FDM)

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The work focuses on the development of the technology of ultra-strong composites based on polymers filled with carbon nanostructures (CNS) for 3D printing FDM. The addition of carbon nanostructures to the polymer matrix makes it possible to increase the strength of such polymer by a factor of 2-3, and the possibility of using such composite in 3D printing will make it possible to create products of any complexity and configuration. 3D printing technology using composites containing carbon nanostructures makes it possible to create unmanned aerial vehicles with the same strength characteristics as metals. However, they have a significant weight advantage. It is impossible to accurately determine the mechanical characteristics of 3D composite products, since the samples are destroyed during pressing, which is due to the porous structure formed as a result of the interaction of carbon nanostructures (CNS) with the polymer. Conclusions. In work for the first time: 1. A product was created from a composite material (polymer and carbon nanostructures)by 3D printing; 2. The product of a 3D composite material has a porosity that increases with an increase in the concentration of carbon nanostructures in the polymer (from 0.05% to 25%); 3. Research results show that the smaller the nanoparticle size, the smaller the pore in the composite for 3D printing; 4. It is shown that the insertion of carbon nanostructures into the polymer for 3D products increases the mechanical characteristics of the product; 5. The optimal percentage of carbon nanostructures (CNS) in solid polymers is about 15%, which allows a 3D product to acquire maximum mechanical strength; 6. It was found that the mechanical strength of 3D products made of composite material increases in direct proportion to the increase in the dispersion of carbon nanostructures that were used in the manufacture of the working composite.

EPR Spectroscopy Study Of Eu2O3 Oxides

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The electron paramagnetic resonance spectroscopy (EPR) spectra for oxides (REEs) show that during thermal treatment of samples from 120°C, 1100°C to 1500°C, changes in intensity, position of spectral lines, changes in the value of g-factor and changes in the shape of the corresponding curves in the spectrum were found. Thermal treatment of oxide samples leads to redistribution in the spectral EPR characteristics and properties of oxides and the dominance of characteristics with the corresponding discrete and continuous values. The spectral characteristics of EPR spectroscopy allow us to draw a conclusion about the mathematical model used and applied in the processing of the shape of the line in the spectrum and the spectral characteristics of samples based on oxides (REE). The corresponding mathematical model contains the use of functions of Gaussian curves, Lorentz and Pearson functions, inverse polynomial and mathematical models of Voigt. The comparative characteristics of these mathematical models include complex spectrum processing and allow to predict the highest quality and best model for the corresponding line in the spectrum of oxides (REEs). In EPR spectroscopy for europium oxides Eu2O3, the characteristics of the ions included in the oxides (REE) can be europium ion Eu0 with a configuration of (8S07/2) and a form of electronic configuration 4f75s25p66s2. The oxide also includes europium ion Eu1+ with configuration (9S04) and electronic configuration form 4f75s25p66s, europium ion Eu2+ corresponding oxide with configuration (8S07/2) and electronic configuration form 4f75s25p6and europium ion Eu3+ corresponding oxide with configuration (7F0) and the form of electron configuration 4f65s25p6.

Acknowledgments

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Mathematical Modeling Of Strength And Plasticity Of High-Modular Skeletal Composites Obtained By Impregnation Method

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In [1], a great potential of the porous skeletal structures based on ultra-coarse-grained WC carbide powders coated with plastic metals (Co,Ni,Cu) was demonstrated. Such composites can be infiltrated with molten metals, alloys, which will give them specific functional properties. Of particular importance is the production of composites, when the WC particles are connected by one material and the pores are filled with another. Their use for friction vapors lubricated with low-viscosity liquids leads to increasing the wear and corrosion resistance, and work of plastic deformation of structural elements. An analytical algorithm (related to the solution of the model problem of thermoelasticity [2]) is proposed to estimate the compressive strength of a hard metals made of porous high-modulus skeletal structure WC by impregnation. The dependence of the limits of strength, elasticity, limit value of plastic deformation, specific works of total and plastic deformations on the phase composition and microstructure parameters of composites of this class is also investigated. It is believed that the coated WC grains form a skeleton with the corresponding value of the contiguity, and the volume content of the phase used for impregnation corresponds to the initial porosity of the composite base. As a result of calculations for the case when the porous skeleton of WC(Co) is impregnated with cobalt, it was found that the elastic and strength limits are weakly dependent on WC grain size (range20to80μm) and cobalt thickness coverage (from1.11μmto7.6 μm). While plasticity increases significantly with increasing dWC and thickness coverage. Similarly, the energy characteristics of the material change as the specific work of plastic and full deformation. For example, for a composite with a volumetric bond content VCo=0,3 and dWC=80μm, increasing the coating thickness from 4.44μm to 7.6μm increases the specific work of plastic deformation by almost 4 times (from 11 to 41 MJ/m3).

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Properties Of Si3N4 Ceramics With Sintering Additives Fabricated By Spark Plasma Consolidation

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Si3N4 is a promising candidate for high-temperature applications and important factor in achieving high mechanical characteristics is the polymorphic alpha→beta-phase transformation into Si3N4 during sintering. The work is devoted to the study of the influence of oxide additives on the phase transformation in Si3N4 under SPS conditions. The influence of Y2O3 & SiO2 on the Si3N4 properties was addressed. Initial mixtures of Si3N4–Y2O3 and Si3N4–Y2O3–SiO2 has been homogenized by planetary ball milling. The subsequent SPS consolidation was performed in a nitrogen atmosphere with heating rate of 50 K/min & pressure of 35 MPa. It was found that the complex addition of Y2O3 & SiO2 promotes the formation of a significant amount of liquid phase and provides compaction by the mechanism of rearrangement of Si3N4 nanoparticles under pressure. The slower consolidation of ceramics added with only Y2O3 was explained by the local interaction of Y2O3 and SiO2, which appears on the surface of Si3N4 particles. It was found that during SPS the complete transformation of Si3N4 requires 30 min exposure at 1800 °C for ceramics Si3N4–Y2O3–SiO2 and more than 30 min for Si3N4–Y2O3. The structure of Si3N4–Y2O3–SiO2 ceramic was observed to be assembled from isometric grains with an average size of 300 nm and anisometric grains of Si3N4 with a length of ~2 μm. In case of Si3N4–Y2O3, the larger size of the corresponding structural elements (~ 2.5 times) may be explained by the significant grain growth during prolonged soaking. The intercrystallite type of fracturing dominates for both Si3N4–Y2O3 and Si3N4–Y2O3–SiO2 ceramics. The Si3N4–Y2O3 and Si3N4–Y2O3–SiO2 composites showed the flexural strength of~950 MPa at room temperature, and gradual decreasing of flexural strength to ~600 MPa with temperature increasing to 1400°C. Obtained room and elevated temperature strength, Vickers hardness of~15 GPa and fracture toughness of ~5.7 MPa·m1/2 meet the current level of requirements for this ceramic.

Interaction Cerium Oxide With Oxides Of Lanthanum And Ytterbium

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Materials based on cerium oxides and lanthanides are widely used in high-tech industries. In recent years, cerium dioxide has been used as a protective coating that absorbs UV radiation, as the main component of polishing mixtures and abrasives, in sensor devices that allow to determine the minimum amount of impurities in gas mixtures, solid electrolytes for fuel cells and others. Highly dispersed cerium dioxide and solid solutions based on it are part of three-way catalysts designed for efficient combustion of car exhaust gases, used in selective oxidation reactions in the dehydrogenation of alcohols, etc. Physico-chemical design of new materials cannot be performed without basic fundamental information about the original components and their interaction under different conditions. The state diagram of the CeO2–La2O3–Yb2O3 system is a physicochemical basis for the creation of materials for structural and functional purposes. There are no data on the thermodynamic stability of solid solutions based on oxides of cerium, lanthanum and ytterbium in the literature, which necessitates the study of phase equilibria in the ternary system CeO2–La2O3–Yb2O3 In the CeO2–La2O3–Yb2O3 system at 1500 □C new phases were not detected. It was established that in the ternary CeO2–La2O3–Yb2O3 system there exist fields of solid solutions based on hexagonal (A) modification of La2O3, cubic modification of CeO2 with fluorite-type structure (F), cubic modification Yb2O3 and with perovskite-type structure of LaYbO3 with orthorhombic distortions. The cubic ceria-based solid solution has a fluorite-type structure and homogeneity field shows the maximum extension. It forms solid solutions of substitution type with phases of binary systems. The boundary of the homogeneity field of F-phase is curved from the center of triangle toward the CeO2 corner and passes through appropriate points in the binary CeO2-Yb2O3 (74 mol% CeO2) and CeO2–La2O3 (51 mol% CeO2) systems.

Large-Size AlN-Base Ceramic Parts For Amplifiers With Virtual Power Supply

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A problem of preparing AlN parts with high thermal conductivity and good dielectric properties arises when designing devices with good data saving during transmitting and processing. Here, wide-band high-voltage electric signal amplifiers are used with minimal distortion of impulse front in the amplification process itself. The large-size parts from AlN-base ceramic material were made and used in design novel amplifiers with minimum losses and distortions of the electric signal are presented. To minimize the losses of electric signal through the parasitic capacitance we decreased capacitance connection by distancing the bodies of operation amplifiers of the broadband high-voltage amplifier from the common bus bar by additional intermediate layer of dielectric with high-thermal conductivity. We have used the fully dense pressureless sintered AlN-base composite (T=1800–1900°C) having thermal conductivity of 120 W/(m•K), preparing parts of it with dimensions of 60×70×10 mm. Employment of the AlN-base dielectric parts had an impact on the capacitance linking with a ground bus. The 5-mm distancing of the amplifier from a radiator element has lowered the parasite capacity to as low as 4 pF. High dielectric properties of parts provides safe operating voltage from 4000 V, and a low capacity characteristics afford necessary qualities for using as dielectric plates for high-voltage amplifiers. AlN-base ceramic parts with high thermal conductivity have been used to develop the wideband high-voltage amplifier with virtual power supply. The developed amplifier with operation voltage of 1 kV and frequency 100 kHz exceeds the parameters of the amplifier commonly used in electrical engineering (voltages 30 V, frequency range 1–50 MHz). Besides, decreasing of sinking currents through a parasite capacity made possible to minimize a distortion of impulse fronts in the process of amplifying thus improving the transmission of information owing to holding the signal shape.

Robocasting By Silicon Carbide And Bioglass Pastes

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It is known the Smartech Publishing presented a report on the development of 3D printing with ceramic materials in early 2019. According to this report the 3D printing ceramic products will reach the level required for industrial implementation in 2025 [1]. Given the pace of the Ukrainian market of medical technologies development is necessary to update the structure and approaches to obtaining high-precision ceramics. The expansion of the market sector for the use of 3D-printing pastes with ceramic components in the total volume of additive technologies has prospects for the development of industries. Methods. To the 3D-printing we used a printer "ZMORPH 3D printer". Two types of charge for medical pastes were used in the studies. The bioglass paste is containing 18.5 wt.% Bioglass (SiO2-NO2O-B2O3), 7.4 wt.% Ethylcellulose and 74.1 wt.% Isopropyl alcohol [2]. Also, after a series of experiments, it was determined that a mixture of 5.05 wt.% Silicon carbide, 6.68 wt.% Agar-agar and the addition of 88.27 wt.% distilled water may be suitable for the preparation of a paste based on silicon carbide. An important factor in 3D printing using Robocasting technology is the size of the product after all technological operations. Main results and Conclusions. The method of preparation of bioglass / gelatin charge and silicon carbide / agar-agar for use as pastes for 3D printer "ZMORPH 3D printer" with Zmorph Ceramic module was experimentally developed. The proportions of the components allowed to obtain a satisfactory quality result when using the paste during 3D printing. Due to the fact that both compositions of the binder paste contain a lot of liquid, after drying the samples of bioglass / gelatin reduce the weight by 30-52%, and silicon carbide / agar-agar by 80-83%. That is, a large porosity is formed, which has significant advantages in medical use in terms of permeability.

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Synthesis Of A MoAlB Ceramic Via Spark Plasma Sintering

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High-temperature ceramics materials based on MAB phases are distinguished by high thermal and electrical conductivity, low density, and high hardness. However most known synthesis methods do not make it possible to obtain the MAB phase of a satisfactory level of purity and include chemical-thermal treatment. The purpose of the work was synthesis of MoAlB ceramic with a minimum content of the undesirable reaction co-products, such as metals oxides via spark plasma sintering technique. Mo, Al, and Mo3B5 powders in the appropriate stoichiometric ratio were used as a raw material. Mixtures of composition Mo+Al+B (1) and Mo3B5+5Al+2Mo (2) were obtained after homogenization in a planetary mill. The jar was filled with argon to prevent the components' interaction with oxygen. The mixed powders were sintered by SPS in a graphite die at 1200°C under a vacuum environment. The obtained specimen's structure was studied using XRD and SEM. The MoAlB phase theoretical diffraction spectrum was developed using Mercury software. It is established that mixture (1) has almost identical to the theoretical diffraction spectrum after SPS. The XRD pattern of mixture (2) has reflections, which is not typical for the theoretical one. Studies of the obtained specimen microstructure have shown that both specimens' structures consist of a matrix and MoB2, Al2O3 inclusions. During synthesis from mixture (1), the MAB phase is formed as large grains with unevenly distributed inclusions. However, many dispersed inclusions are formed in the matrix volume during synthesis from mixture (2). In conclusion, single-phase MoAlB can be successfully synthesized via SPS. XRD and SEM analyses have shown that it is advisable to use powders of pure elements. Further studies should establish the initial materials type influence on the MoAlB final properties.

Size Dependence Of Plasticity Determined By The Indentation Method

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The plasticity characteristic (δ*) was introduced in [1] as a “dimensionless parameter determined by the ratio of plastic deformation to the total elastoplastic deformation in the direction of loading”. The δ* can be determined by different methods of mechanical tests (tension, compression, bending) and by indentation. For instrumental indentation, which is extensively used in determining of nanohardness, for characteristic of materials plasticity the δ* was introduced as the ratio of the work of plastic deformation to the total work expended on the formation of a hardness indent [2]. The introduction of the δ* made it possible to classify almost all materials, both plastic and brittle ones in standard mechanical tests, from the value of plasticity. For materials the correlation and combination of the values of hardness and plasticity are important. Since the δ* depends on the hardness of the material in which indentation size effect (ISE) is observed, δ* also has a size effect. A decrease in the load on an indenter and a reduction in the size of a hardness indent in crystalline materials leads simultaneously to an increase in the value of the hardness and a decrease in the δ* [3]. For a number of ceramic materials (BeO, MgO, TiN, ZrN, NbC, ZrC, WC, SiC, etc.) a theoretical calculation of the change in the δ* from the indenter penetration depth (h) was made. For all values of indenter displacement, a rather sharp size dependence of the δ* is observed, especially at small values of (h), which is typical for nanohardness. To eliminate the influence of ISE on the hardness and δ* of high-hard materials, it is proposed to determine the value of the δ* at a fixed value of the indenter penetration depth h=100nm (rather than at a fixed value of load on an indenter), which corresponds to the standardization of the sizes of specimens in mechanical tests. This approach will make it possible to more correctly compare the results of hardness and δ* obtained in different studies.

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High-Speed Sintering Methods For Hard Alloys

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Traditional vacuum technologies of free sintering are not effective for producing hard alloy materials with nanostructures or fine structures. One way to inhibit grain growth in hard-alloy mixtures consists in applying pressure during sintering, which allows to reduce the consolidation temperature. Heating with high rate, as well as applied pressure, allow to reduce the sintering temperature to 1200 – 1300°C. Thus, it is necessary to study in more detail the features of consolidation of the WC-based hard alloys under the conditions of rapid sintering techniques, including those with electron beam application. The goal of the work was to establish the effect of sintering conditions on the microstructure, phase composition, and properties of a hard WC-based alloy with 8% Co (VK8). The effect of sintering regimes on the microstructure, phase composition, and properties of the hard alloy VK8 has been studied. It is shown that the conditions of rapid sintering methods, such as spark-plasma and electronbeam sintering, provide the formation of fine-grained microstructure, high hardness and microhardnessin the hard alloy VK8. The featuresof the microstructure formation, namely the precipitation of small amount of the η-phase with increasing exposure time during electron beam sintering, are revealed for rapid methods. The correlation between the sintering kinetics and the microstressesin the phase constituents of the hard alloy VK8 is shown. The studies have shown the prospects of rapid sintering techniques for hard alloys and their advantage over traditional furnace sintering.The results can be used in the development of the cores of small armor-piercing ammunitions.

Elements Of Computer Design Of AlB_{12} – Al_2O_3 Ceramic Composition

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The component of prediction of computer design of advanced materials in of refractory compounds has revealed a high potential of performance of AlB_{12}-Al_2O_3 composition system, which combines useful qualities of non-oxide and oxide components. The experimental possibility of obtaining new functional materials with high strength, hardness, heat resistance and ability to withstand ballistic loads, given that the mechanical properties of AlB_{12}-Al_2O_3 ceramics have not yet been studied properly, is of extremely importance nowadays. Therefore, a prime goal of this effort was to obtain ceramic AlB_{12}-Al_2O_3 samples in a wide range of mutual concentrations by hot pressing and systematic study of their mechanical and other functional properties depending on composition of ceramic material. For these studies, compositions in a wide range of AlB_{12} and Al_2O_3 concentrations were prepared from one source batch of individual components. Samples mechanical characteristics like density, microhardness, and structural properties, which are characterized by multifractal dimensions, were studied. The obtained values of multifractal dimensions demonstrate that at mass content of alumina of 50% a boundary system is mostly developed, and microhardness arrives the maximum value. Thus, it is confirmed that microhardness is structurally sensitive characteristic that depends primarily on development of boundary system. The obtained results may serve as a solid background for further research targeted on development of methods for obtaining reasonably cheap compact materials in AlB_{12}-Al_2O_3 system with a sufficient level of performance properties. The developed method of characterization of structure of materials on the basis of fractal geometry methodology, on the considered example, demonstrates a possibility of establishment of correlation of values of multifractal characteristics of structure with mechanical properties of composite materials.

Interaction In Cerium Oxide (+3) And Oxides REE Of Yttrium Subgroup Systems

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The interaction in the systems of Ce2O3 and (Tb–Lu,Y)2O3 is of interest due to the prospect of using complex ZrO2 stabilizers to create new high-temperature thermal barrier coatings. The interaction between lanthanide oxides consists in the formation of continuous solid solutions between the components, as well as areas of solid solutions with different (X, H, A, B and C) Ln2O3 structures. In addition, ordered phases with a LnILnIIO3 perovskite-like structure appear in some of these systems. Investigations of lanthanide oxides polymorphic transformations by the method of derivative thermal analysis lead to the conclusion that all lanthanide oxides are characterized by the formation of all structural forms (X, H, A, B and C). For lanthanides of the yttrium subgroup (Tb − Lu, Y), the temperature regions of X, A, and B structures are very narrow and do not exceed 5–10 ºC [1]. For technological developments, the presence of such narrow homogeneity areas does not play a crucial role, but when constructing phase diagrams they should be taken into account. Tentative phase diagrams of unexplored Ce2O3−(Tb−Lu)2O3 systems have been constructed on the basis of experimentally constructed phase diagrams and established regularities. The polymorphic transformations of lanthanide oxides established by derivative thermal analysis were taken into account.

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The Alloys Of Nb–Si–B System For High Temperature Application

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Benefiting from the incorporation of silicide (Nb5Si3 or Nb3Si) reinforcements into ductile matrix (Nb), the Nb–Si–B in situ composite system becomes one of the most competitive candidate materials for next-generation application in aerospace with its remarkable physical and mechanical properties. The urgency and expediency of the work are caused by today's challenges to materials that operate in conditions of high and cyclic loads, aggressive environments, etc [1, 2]. In this regard, more and more attention is paid to the use of composite materials with metal matrices that include refractory compounds, the spread of which in the industry is constrained by the complexity of manufacturing products due to high energy consumption of processes and significant capital and material costs. Therefore, the development of new materials is one of the most promising ways to replace existing materials that have exhausted their capabilities by creating metal-ceramic and metal composites with multifunctional ability. The materials of Nb–Si–B system provide high reliability and necessary resource for gas turbines, as well as high oxidation resistance. The work aims is to create new structural high-temperature materials that can replace nickel-based superalloys and ensure operation at high temperatures (above 1000 °C). It was established the microstucture consists of metal matrix (Nb) reinforced by fibres of Nb silicides and Nb borosilicide. The alloys have high strength (more than 1500 MPa) and stress intensity factor near 25 MPa*m1/2, capable of operating at high temperatures, more than 1200 °C, and dynamic alternating loads, intense abrasive wear, high pressures, and sliding speeds. The research results allowed to establish optimal alloys for use as materials for gas turbines (with an operating temperature above 1200 °C).

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Electron-Beam Sintering Of WC-Based Cermets With High Entropy FeCrNiWMo Binder

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According to recent research, there are two most promising ways to improve the properties of WC-based carbides. The first way is to use methods such as electron beam sintering (EBS), which, due to the high sintering speed, provide fine-grained WC [1]. The second way is to use new binders, such as high entropy alloys (HEA), which improve the properties of the hard alloy compared to commercial WC–Co ones [2][3]. So, the aim of this work is to obtain WC-based cermets with HEA binder by EBS. Commercial WC powder (90 wt. %) with a particle size of 4-6 μm and a FeCrNiWMo HEA (10 wt. %) obtained by mechanical alloying were chosen as starting materials. Mixing was carried out in a planetary ball mill (1 h, 200 rpm, alcohol), and EBS was carried out on the ELA-6 machine (1450 °C, 4 min). Sintered samples were investigated by XRD and microstructural analyses. The Vickers microhardness at 1 kg load was also measured. The density was determined by Archimedes principle. As a result, samples with a high relative density of 99 % were obtained. XRD analysis of the sintered samples showed the presence of three phases, namely WC, HEA (bcc solid solution) and WC 1-x. First, we should note the presence of the HEA phase, which indicates the absence of strong interaction of WC and HEA during EBS. Second, there is the formation of a third WC 1-x phase, which, however, does not register on the microstructure of the samples. This can be caused by the high sintering rate and presence of small oxide layer, which leads to the formation of very fine WC 1-x grains at the grain boundary or on the surface of the particles [4]. The microhardness of the sintered samples becomes 18.9 GPa, which can even be improved by further particle grinding. The results indicate that the obtained composites have a high density and hardness; therefore, it is promising to use both the high-speed EBS method and FeCrNiWMo HEA as a binder instead of Co to improve the properties of WC-based cemented carbides.

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Obtaining Of ZrB2-CrB Composites At High Pressure

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Refractory borides have a high melting point, wear resistance, hardness and stability of properties over a wide temperature range. These properties make them promising materials for creating abrasive-resistant composites based on them with an extended service life at high temperatures. Due to the low diffusion mobility of borides, reaction sintering under pressure is used to obtain high-dense composites based on them [1]. The aim of the work was to obtain high-dense ceramic ZrB2-CrB composites with an estimated CrB content of 20-80 wt. % by reaction sintering under high pressure of 4 GPa in the temperature range of 1400-1800 o C and a holding time of 60 s. As starting materials, micro-powders of zirconium (<4 microns), chromium (<40 microns) and submicron powder of amorphous boron (<0.3 microns) were used. A high-pressure device of the "anvil with recesses" type was used for sintering composites [2]. The density of the obtained samples was determined by Archimedes method in CCl4. XRD, EDX methods and microhardness measurement were used for the studies of samples. It was found that at low sintering temperatures of 1400-1600 o C, in addition to ZrB2 and CrB, insignificant amounts of unreacted zirconium and chromium are present in the composites. The formation of other chromium borides Cr3B4, CrB2, Cr5B3 was found too. Increasing the sintering temperature to 1800 o C contributes to the most complete reaction between the initial components. At the same time, two-phase composites were obtained only in the ZrB2-20%CrB and ZrB2-70% compositions. ZrB2-CrB composites with relative density up to 99.9 %, microhardness HV0.2 15.1-18.1 GPa and fracture toughness K1C 4.5-9.0 MPa•m1/2 were obtained.

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Effect Of Chromium Additives On Nanohardness Of SiC-Based Ceramics

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In context of the fight against global climate changes and achievement of decarbonization, there is a growing global demand for “clean” energy, which is characterized by the low or zero greenhouse gas emissions. Nowadays, it is recognized that nuclear energy belongs to this type of energy. The most optimal solution for countries with advanced nuclear industry is a policy, aimed at maintaining or increasing the share of nuclear energy in their energy systems, which will lead to an increase in the amount of radioactive waste. Therefore, the safe management of radioactive waste (RAW) is one of the main factors to ensure the environmental friendliness of nuclear energy. SiC-based ceramics is a promising material for high-level waste (HLW) containers due to its physical, mechanical and chemical characteristics. Therefore, studies aimed at improving the performance of SiC under severe operating conditions are relevant. In this study the effect of chromium (Cr) additives on nanohardness of SiC-based ceramics is analyzed. Samples with Cr additives from 0.3 to 0.9 wt.% were obtained by high-speed hot pressing (HSHP) method. Nanohardness of the SiC(Cr) samples was determined by nanoindentation using the Nano Indenter-G200 system (Agilent Technologies, USA) equipped with Berkovich diamond tip. Ten indentations were made on each sample. The depth of indentation was approximately 500 nm. The measurements showed that the addition of chromium in the range of 0.3 ÷ 0.7 wt.% leads to an increase in nanohardness compared to pure SiC. For example, the nanohardness of SiC with the addition of 0.5 wt.% Cr is 37.8 GPa, while in pure SiC - 31.0 GPa. Increasing the Cr content to 0.9 wt.% leads to a sharp decrease in nanohardness from 37.8 GPa to 27.0 GPa. The effect of Cr additives (in the range of 0.3 ÷ 0.9 wt.%) on the nanohardness of SiC-based ceramics is shown. Obtained results can be taken into account and influence the further choice of ceramic materials for HLW containers.

The Effect Of Y2O3 Addition On The Electrical Parameters Of TiN Oxide Based Varistors

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The tin oxide based varistors are used to protect the electrical devices from overvoltage. Such varistors have the nonlinear current-voltage characteristics. Adding the different oxides to the SnO2 we improve the electrical characteristics of tin oxide based ceramics and modify its microstructure. Nb2O5 oxide is used to raise the electrical conductivity of SnO2 grains while Cr2O3 oxide increases the nonlinearity coefficient. In this paper we share the results of Y2O3 oxide addition usage which leads to the decrease of the low-field electrical conductivity and the leakage current of ceramics. In this investigation the electrical characteristics of (99.9-x) SnO2 - x Y2O3 - 0.05 Nb2O5 - 0.05 Cr2O3 ceramics (x = 0, 0.3, 0.5, 0.7 and 4.0 mol.%) baked at 1400C (1 hour) are considered. The samples were obtained by wet-milled method and traditional ceramic technology (disks 11 mm in diameter, 0.7 mm thick, axial pressure of 45 MPa). The Ag-electrodes (800C, 10 min) were prepared for recording the electrical characteristics of samples. Scanning electron microscopy and X-ray diffraction analysis were used for the investigation of sample microstructure. The studied samples with Y2O3 addition consist of SnO2 grains and small particles of Y2Sn2O7 pyrochlore phase. The size of SnO2 crystallites is 4.2-4.5 μm and the size of Y2Sn2O7 particles is equal to several fractions of micrometers. The agglomerates of Y2Sn2O7 secondary phase restrain the growth of SnO2 grains and are responsible for the high breakdown voltage of varistors. The studied materials have high nonlinear current-voltage characteristics. The SnO2 based ceramics with 0.5 mol.% Y2O3 addition has the largest value of nonlinearity coefficient (approximately 50) at breakdown electric field 15 kV/cm. Such ceramics has the activation energy of electric conduction 0.9 eV and the lowest low-field electrical conductivity 2.9 pS/cm. These parameters are explained by the high Shottky type potential barriers on the grain boundaries of ceramics.

Features Of The Formation Of Hot-Pressed Heterophase Ceramics Based On Boron Carbide

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The features of the formation of hot-pressed single-phase ceramics with high characteristics based on technical boron carbide powders are complicated by the high content of free carbon in them. The addition of additives in the form of oxides into the composition of the initial charge for obtaining ceramics from boron carbide contributes to the production of a high-density heterophase material with a high level of physical and mechanical properties. In this work, optimization of the composition and process of obtaining hot-pressed ceramics with improved characteristics based on boron carbide was experimentally carried out by choosing activating additives and their amount to technical boron carbide and assessing the stress-strain state of the material. The effect of the activating impurities in the form of oxides on the formation of its physical and mechanical properties was determined by the method of indentation of heterophase ceramics of different compositions. As a result of the studies of the features of the formation of heterophase ceramics based on boron carbide, it was found that the usage of SiO2, TiO2, and Cr2O3 additives helps to reduce the hot-pressing parameters for obtaining high-density heterophase ceramics. In the process of hot reactive pressing of boron carbide with oxides, heterophase ceramics of the composition B4C - (Si, Ti, Cr)B2 are formed, during the preparation of which it is possible to effectively use technical boron carbide powders with a high content of free carbon. In this case, ceramics of the composition B4C-(CrB2+TiB2), B4C-CrB2 are formed, in which abnormal grain growth is inhibited, which ensures a high level of mechanical properties compared to single-phase ceramics. The bending strength of such ceramics is 600…800 MPa, which is two times higher than that of single-phase ceramics.

Optimization Of The Ceramic Polymer Armor Structure And Composition

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Experimental studies of the dynamic interaction of ceramic materials and ceramic-polymer armor with armor-piercing indenters are highly actual for optimizing the composition and controlled impact on the structure and properties of protective products. The method of the investigation of breakdown parameters with the registration of the shock impulse using a ballistic pendulum has been chosen and improved for experimental part of the work. This technique allows to make quantitative evaluation of shock resistance for ceramic materials and ceramic- polymer armor products before breakdown based on the interaction conditions, physical and mechanical properties, and geometric parameters of an obstacle. Experiments have shown the rationality of armor resistance evaluation for ceramic materials based on empirical criteria taking into account the fraction of the initial indenter impulse spent on the breakdown of a material of a specific density and thickness. The obtained research results are used in the technological process of manufacturing ceramic-polymer armor to control the quality (parameter compliance) of ceramic protective elements, for example, during the input control of materials.

SYNTHESIS AND PROPERTIES

Selected Boride Materials for Different Applications

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Borides offer large possibilities for different applications. Although they are often acknowledged for their mechanical properties and refractor character, they show many other outstanding features. In our research we pay attention to selected borides, exploring different properties for their better understanding and control. We are evaluating the multifunctional potential of boron, which allows us to extend its scope.Borides are in general difficult-to-sinter materials due to their strong covalent character. Hence, high sintering temperature is needed and pressure-assisted activated sintering methods such as spark plasma sintering (SPS) can overcome this problem.All samples presented in this work were fabricated by SPS and had a high relative density, above 97 %. Dislocations in B4C from B4C-Pt and TiB2-B4C refractorycomposites were studied.Evidences for dislocations rearrangement under mechanical load in bending experiments at temperatures up to 1800℃ are discussed based on transmission electron microcopy investigations performed on the samples before and after bending tests. A twin rearrangement mechanism is proposed. After high temperature bending, twins with unusual mismatch angles were revealed. Twins-related effects are thought to significantly contribute strengtheningbehavior at high temperatures. Magnesium diboride (MgB2) shares a similar hexagonal layered crystal structure with refractory borides TiB2, ZrB2, CrB2. Nevertheless, MgB2 is prized for superconductivity. In our work we fabricate MgB2 composites that can be machined by chipping. These materials are shown to be useful for bulk superconducting magnet and magnetic shield applications. Partially textured bulk MgB2 obtained by high magnetic field slip casting and SPS is addressed. Our recent developments of MgB2 for biomedical applications as a biodegradable, antimicrobial, and antitumor material are also briefly presented.

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First Principles Study of Amorphous Boron Suboxide and its High-Pressure Behavior

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Using ab initio simulations, a boron suboxide (B6O) amorphous model is generated form the melt. The model consists of boron and oxygen-rich regions, which are structurally similar to amorphous boron and boron trioxide (B2O3), respectively. The amorphous configuration has a small band gap energy than the crystal. Bulk modulus and Vickers hardness of the amorphous phase is projected to be 106 and 13-18 GPa, correspondingly, which are noticeably less than those of the crystal. Such a visible decrease in the mechanical properties is attributed to the existence of open structured B2O3 glassy domains in the amorphous model. With the application of pressure up to 100 GPa, the model undergoes a polyamorphic (amorphous to amorphous) phase transformation having a steady increase in the average coordination of both boron and oxygen atoms. The pressure-induced changes occur predominantly around oxygen-atoms and the regions connecting the pentagonal pyramid-like motifs to each other. On pressure release, an amorphous structure being about 10% denser than the original state is recovered, suggesting a permanent densification and a possible irreversible amorphous-to-amorphous phase transformation in B6O. The recovered amorphous configuration shows slightly better mechanical properties than the original model. During the compression and decompression processes, amorphous B6O remains semiconducting.

Specially Engineered Zr-Ta Multiboride Ceramic With A Supercomposite Structure

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It is well established that the borides of transition metalsare being widely used for a variety of application including thermal protection systems, cutting tools, etc. Due to the recent interest in ultra-high-temperature ceramics (UHTCs) capable of withstanding high-temperatures and high external loads in severe or extreme environments, the interest to zirconium diboride based composites is particularly high. The present study focuses on the processing and mechanical properties of the specially engineered ceramic composite that contains only boride phases of Zr and Ta with an artificially created hierarchical superstructure.Such composite was formed during the reaction-driven consolidation process using a mixture of ZrB2, tantalum and amorphous boron powders. The homogeneity of the reaction between these powders allowed the formation of a highly reproducible and repetitive superstructure where Ta3B4 forms a chain-like mesh which entraps the ZrB2, ZrB, TaB and (Zr,Ta)B2 phases. The multiboride ceramic composite exhibited extremely high hardness: 28.6±3.2 GPa or 22.6±0.6 GPa under 98 N and 196 N loads, respectively. The primary reason for the high hardness of multiboride ceramic composite was considered to be the formation of the (Zr,Ta)B2 solid solution. The main phase of the multiboride ceramic was the solid-solution of zirconium and tantalum diborides which is thought to improve the flexural strength up to 2000 °C when compared to the bulk ZrB2 data. At 2000 °C, the multiboride composite showed a strength of nearly 400 MPa and fractured in an elastic manner at the loading rate of 2.5 mm/min. This level of strength is usual for the bulk zirconium diboride at room temperature.We analyzed the fracturing at different temperatures and found that it is highly likely that formation of the step-like structure of the boride grains at 2000 °C can be reasonably interpreted as the vaporization of boron from the surface of the boride grains.

Thermodynamic Properties Of Liquid Glass-Forming Alloys Of Multicomponent Early With Late Transition Metals Systems

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Interest on the thermodynamic properties of liquid alloys of hafnium, titanium, zirconium – early transition metals (ETMs) with cobalt, nickel, and copper – late transition metals (LTMs) concerns the development and production of rapidly quenched and bulk amorphous alloys. Also, this information is necessary for the effective development of new materials, such as crystalline and amorphous high entropy alloys. The thermodynamic mixing functions of multicomponent liquid alloys were calculated using a thermodynamic database for the Co–Cu–Ni–Ti–Zr–Hf glass-forming system. The database was developed in the spirit of CALPHAD approach. The parameters of the database were generated using experimental data on the thermodynamic mixing functions of liquid alloys in constituent binary and ternary systems. As the thermodynamic mixing functions of binary and ternary liquid alloys formed by ETMs and LTMs demonstrate strong negative deviations from Raoult's law the associate solution model was used for their modelling. The concentration and temperature dependencies of the thermodynamic functions such as mixing enthalpy, excess mixing entropy and Gibbs energy, and mixing entropy and Gibbs energy of the Co−Cu−Ni−Ti−Zr and Co−Cu−Ni−Ti−Hf liquid alloys were analyzed. It was shown that the negative deviations from ideality increase with decreasing temperature. The important role of the pair interactions between ETMs and LTMs in definition of concentration dependence of the excess thermodynamic functions was demonstrated. The mixing Gibbs energy and it's contributions were calculated for 6 equiatomic quinary liquid alloys of the Co–Cu–Ni–Ti–Zr–Hf glass-forming system. The contribution of the ideal component of the mixing Gibbs energy was analyzed in the interval of temperature from 800 to 1873 K.

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Application Of CALPHAD Method For Materials Design

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In the frameworks of CALPHAD (Calculation of Phase Diagrams) method, the experimental information on the thermodynamic properties of phases and phase equilibria in the system is converted into optimized parameters of Gibbs energy models of the phases. The term “thermodynamic assessment of the system” indicates that the parameters of thermodynamic models of phases of the system obtained in such way that the thermodynamic properties of phases and the phase diagram of the system can be calculated simultaneously. CALPHAD method allows to summarize and clarify in the one model the data on phase equilibria and thermodynamics of phases and is a powerful tool for theoretical research and establishing of the most accurate information. The model parameters can be summarized in self-consistent databases for multicomponent systems and can be applied for the development of new materials. Different problems associated with equilibrium transitions in multicomponent materials such as the temperature-composition boundaries of phase range, the determination of the optimal concentration of additives, or analysis of the dependence of the phase composition on temperature, for example, can be solved. Also, the questions associated with the occurrence of metastable transformations in the systems leading to the formation of amorphous alloys, supersaturated solid solutions based on pure components and intermediate phases. This report covers a wide range of issues, such as examples of thermodynamic descriptions of binary and ternary systems, development of the databases for the quinary Cu–Ni–(Fe, Co)–Ti–(Zr, Hf) and Co–Cu–Cr–Fe–Ni systems. We will also consider examples related to the prediction of concentration regions for obtaining materials with different morphological structural features, and crystalline and amorphous high-entropy alloys.

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Effective Adsorbents Based On The Mesoporous TiO2 For Adsorption And Separation Of Heavy Metal Cations

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Problem statement an objective Purifying aqueous solutions from heavy metal ions and radionuclide contamination is a highly complicated topic, which is very relevant for Ukraine. The need for adsorption and separation of radionuclides may be related to water purification and environmental monitoring after the ChNPP accident. Furthermore, selective adsorption and separation of some radionuclides is an important stage of the production of radiopharmaceuticals. In addition, the separation of radionuclides can be used in archaeological dating. Mesoporous TiO2 with chemically impregnated functional groups can actively adsorb heavy metal ions of Sr2+, Y3+, Cr3+, Ba2+, and Zn2+. This work aims to investigate the new adsorbent materials based on anatase modification TiO2. Methods Adsorbents were synthesized by the sol-gel method. The structure and morphology of the TiO2 and TiO2 with chemical modified surfaces were analyzed using XRF, FTIR, SEM, and EDS methods. The adsorption ability of the adsorbents toward heavy metal cations was tested using direct complexometric titration and ICP-MS analysis in some cases. Main results and conclusion The adsorbents based on anatase modification TiO2 possess a high adsorption capacity toward heavy metal cations, for example, Sr2+ and Cr3+. Sodium modified TiO2 possesses a high adsorption capacity toward Cr3+. The analyzed samples of TiO2 possess a high ability to regenerate and keep high adsorption capacity toward Sr2+ even after several adsorption-desorption cycles. Furthermore, it was shown that investigated adsorbents have unique adsorption properties and increased usage in the separation and purification process.

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I want to say thanks to all Ukrainians

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Use Of Machine Learning Methods To Predict The Processes And Results Of High-Voltage Electric Discharge Treatment Of Titanium Powder In Kerosene Using Spark Discharge

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High-voltage electric discharge (HVED) treatment of powder mixtures is one of the modern methods of grinding and changing the phase composition of powders, which has high efficiency and low cost of the process is compared to classical grinding methods. However, the physical mechanism of dispersion processes when using HVED in a liquid has not been studied enough. Given this, the use of the method of modeling on large data sets (machine learning) can give more accurate results in predicting the processes and results of HVED processing. The goal of this work is to study the possibility of using machine learning methods to predict the processes and results of high-voltage electric discharge treatment of Titanium powder in kerosene. Methods Logistic regression, was chosen as the modeling algorithm. Python programming language and the Colaboratory application (Google Research) were used for the implementation of this method. The results of processing the initial Titanium powder in kerosene using a single-point electrode system, obtained in the period from 2013 to 2021, were used as a data set for modeling. Main results and Conclusions As a result of the work, distribution surfaces for the plasma temperature in the discharge channel (with an accuracy of 40%), the values of the pressure in the discharge channel (with an accuracy of 40%), the pressure on the chamber wall (with an accuracy of 50%), the average particle diameter of Titanium powder (with an accuracy of 60%), the amount of Titanium carbide formed during processing (with an accuracy of 80%), depending on the interelectrode gap and the number of pulses, when using spark discharge and with Titanium powder concentration in kerosene of 0.07 kg / dm3, pulse repetition frequency 0.3 Hz and the energy of single discharge of 1 kJ, were obtained. The possibility of using machine learning methods to predict the processes and results of high-voltage electric discharge treatment of titanium powder in kerosene was shown.

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Densification Dynamics Of WC – 36 Wt. % Cu Cermet During Impact Assisted Sintering In Vacuum

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Currently, tungsten-carbide-based cermets with a high content of silver or copper binder are effectively used as materials for electrical contacts and thermal barriers in plasma torches. Products with a relative density of about 95% are obtained by pressure assisted sintering (in the range from 25 to 45 MPa) powder mixtures at temperatures from 1173 to 1273 K for several minutes. In this work, by trial and error method using a third-order dynamic system [1] and the results of an experimental study of impact assisted sintering of fine-grained tungsten-carbide-based cermet with a content of 36 wt. % (corresponding to a content of 49.67 vol. %) of the copper binder at temperatures 1023, 1123, 1223 and 1353 K in vacuum with an initial impact velocity of 6.4 m/s, computational simulation of its densification dynamics was carried out. As a result of the simulation, the previously unknown average values of the dynamic shear viscosity of the deformable porous cermet as well as the duration of impact loading, the time dependences of the force, compression, velocity and acceleration of the system, the current density of the sample, and the work of densification were determined depending on the impact velocity, stiffness and reduced mass of the impact machine working elements and the process temperature. The energy dissipation in deformable samples induces a mechanical-thermal effect which is expressed in a significant increase in the current temperature of porous cermet samples. The estimated activation energy of the viscous flow of the matrix forming the porous cermet is 0.276 eV or 26.6 kJ/mol. Estimates of the mechanical properties of samples obtained by impact assisted sintering show a significant increase in their strength compared to samples pressureless sintered at a higher temperature.

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Hydroclusters size estimation in the colloid suspension

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In the colloid processing methods, the suspension subjected to shear forces forms a flat film. Suspensions consist of solid particles and polymers which form agglomerates, coils, and hydro clusters. The density, thickness, and roughness of films are defined by the number, shape, and size of these structural elements. Theoretical estimation of their size is of great interest due to the limitation of direct observation and the change of suspension structure under the shear. Combined with rheological studies, these calculations can help in setting up the optimal processing parameters to obtain high-quality films. A modified equation for Gibbs free energy which describes the homogeneous nucleation of a new phase from the gas [1, 2] can be used for cluster size estimation. In the original equation, the change of chemical potential is equal to Boltzmann's constant and temperature multiplied by the logarithm of pressure ratio. For a colloidal suspension, the pressure can be replaced by the particle concentration [3]. As an analog of surface energy, surface tension can be used [1]. To link the obtained from rheological studies suspension viscosity to surface tension, an analog of the mathematical model developed in the work [4] was used. This approach enables the calculation of cluster size with the change of viscosity due to mechanical shear. The volume of a single cluster and the number of particles in it can be calculated using a developed mathematical model that describes the geometric parameters of the spherical agglomerate with adjustable porosity. To estimate the size of the polymer coil, the algorithm based on Flory's theory was developed. The algorithm builds a 3D model of the coil with a preset number of monomers of a certain length. With the ability to set a diapason of random bend angle between monomers, it is possible to emulate solvent conditions and shear stretching of the polymer coil. Calculations of cluster size were verified by optical profilometry.

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Influence of HfC, VC, NbC, TaC, Mo2C and WC on the oxidation resistance of ZrB2-SiC ceramics

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Ultra-high temperature ceramics based on zirconium diboride are famous for their high oxidation resistance and high strength at extremely high temperatures (more than 2000℃). The problem of high-temperature strength is solved by the introduction of refractory additives and special methods of densifications that make it possible to create strong grain boundaries. However, the problem of high temperature oxidation resistance is still an open question. In this case, we studied the influence of HfC, VC, NbC, TaC, Mo_2C and WC on high-temperature oxidation resistance to ZrB_2-15 vol.%SiC It was found that the addition of carbide additives (Mo_2C, WC, Nb, TaC, HfC, VC) to the ZrB_2–15 vol.% SiC results in a change of oxidation mechanism, which increases the oxidation resistance to the level of the most oxidation resistant composite ZrB_2–15 vol.% $MoSi_2$. During oxidation of ceramics, three oxide layers are formed: the upper layer is based on B2O3 – SiO_2, the middle layer is based on ZrO_2 and the lower layer is depleted of boron and silicon. At the initial stage of oxidation, oxygen interacts with the (Zr, Me)B_2 shell around zirconium diboride grains. In the case of the (Zr, Ta)B_2 shell, fine-grained oxides based on tantalum oxide are formed first, because oxidation of tantalum boride is a more energy-efficient reaction compared to oxidation of zirconium boride. In the case of (Zr, Mo)B_2 or (Zr, W)B_2 shells, oxidation occurs simultaneously and is accompanied by the formation of MoB and W, since the activation energy is the same for zirconium additive and diboride. Due to the interaction of oxygen with the shell (Zr, Hf)B_2, a more oxidation-resistant shell is formed from a solid solution of (Zr, Hf)O_2 with a zirconium oxide core. Thus to create ultra-high-temperature ceramics with high oxidation resistance, it is necessary to form a structure (core-shell) in the material controlled by the choice of activating additive and technological parameters of ceramics.

The Influence Of Noble Metal Dopants On Phase Transformations Of Titanium Dioxide Nanopowders At The Temperature Of 1000°C

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Currently, titanium dioxides are used as photocatalysts that are effective under the influence of UV irradiation. To enhance the efficiency of photocatalysis under visible light TiO2 is doped with rare and noble metals (NM), as well as the rutile admixture is injected into the anatase powders' composition.But the nature of the NM significantly affects the T polymorphic transformation in the anatase - rutile system. The aim of the present work was the phase composition' characterization of anatase powders doped with NM and heated at T = 1000 °C. Composite powders based on TiO2 were formed in a low alkaline medium via co-precipitation of titanium(IV) isopropoxide with water solutions containing Au3+, Pt4+ or Pd2+ in the presence of nucleating and reducing agents. Hydroxide precipitates were rinsed several times and dried at T = 160 °C. The calcinations of doped powders were performed in two steps: within 2 h at T 600 and 1000 °C. The main methods of the investigation were XRD , TG-DTA, and SEM/EDS. Regardless of the presence and nature of NM, only the anatase phase was identified by XRD in the powders obtained at T = 600 °C. The incorporation of NM into anatase structure was confirmed by varying the crystal lattice parameters and CSR. For samples heated at T = 1000 °C, the only rutile phase was determined for TiO2&Pd system, while anatase, rutile, and brookite have been identified in pure TiO2, TiO2&Au and TiO2&Pt systems. The anatase phase transformation into rutile in TiO2&Pd system took place at T = 780 °C, whereas the same reflex hadn't been detected in other studied systems. The average particle size of anatase was increased from ~30 to ~300 nm at T = 1000 °C heating. EDS confirmed the inclusion of NM in TiO2 structure. Thus, the presence of palladium in the system initiates the anatase phase transformation to rutile, while the formation of rutile in pure TiO2, TiO2&Au, and TiO2&Pt systems requires an increase in temperature or duration of sample heating.

Comparative Investigation Of Adsorption Kinetic Of Water Vapors On Magnetite Nanopowders Prepared By Chemical Precipitation And Thermal Decomposition

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Magnetic nanomaterials (including magnetite) are widely used in medicine. The shape and particle size in combination with magnetic properties determines its field of application, and knowledge of adsorption kinetics provides knowledge about the technological properties and predicts the adsorption properties of composites based on magnetite. Magnetite powders were synthesized by chemical precipitation of iron chlorides (5, 30 min and 1 h) and thermal decomposition from FeC2O4 at 470 °C in N2 or CH media. Morphology was evaluated by SEM and AMIS software, SSA – by nitrogen adsorption-BET method. Adsorption–desorption were studied by the gravimetric method. An air flow with 100% relative humidity was used for water vapor adsorption. Desorption was analyzed at partial pressure of water vapors in the air flow decreased to 70% and in nonisothermal conditions (temperature increase and decrease in the range 15–80ºC). According to the study of absorption of water vapor on the synthesized powders it was established that the most intensive adsorption process occurs in first 30 min and adsorption ability of magnetite prepared by precipitation method more than 10 times higher in comparison with powders obtained by decomposition. It correlates with the values of SSA of magnetite prepared by different methods. In addition, it was shown that the nitrogen media in comparison with the hydrocarbon allows twice increase the adsorption properties of magnetite prepared by decomposition. The best adsorption ability has magnetite prepared by chemical precipitation for 5 min that which makes it promising for further research and obtaining composites based on it.

Solid-State Synthesis And Characterization Of $(Ba_{1-x}Sr_x)_7Nb_4MoO_{20}$ Powders For SOFCs

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The efficiency of solid oxide fuel cells is highly dependent on the conductivity of the electrolyte. Extensive efforts are now being focused on developing new proton-conducting electrolytes. Recently, high proton and oxide ion conductivity was found in $Ba_7Nb_4MoO_{20}$ perovskite, the properties of which can be improved by doping [1], [2]. However, the synthesis of $Ba_7Nb_4MoO_{20}$ has been little studied in the available literature. Therefore, we tailored the synthesis parameters of $(Ba_{1-x}Sr_x)_7Nb_4MoO_{20}$ and investigated the properties of the obtained powders. $(Ba_{1-x}Sr_x)_7Nb_4MoO_{20}$ (x = 0; 0.05; 0.10; 0.15; 0.20) powders were prepared by solid-state synthesis at 1000–1100 °C (step 20 °C) for 10 h, while the number of repeated synthesis operations was varied from two to four to determine the best reaction parameters for obtaining the maximum concentration of the required phase. XRD, SEM, and laser diffraction were used to characterize the powders. It was found that the most favorable temperature interval for solid-state synthesis of $(Ba_{1-x}Sr_x)_7Nb_4MoO_{20}$ (x = 0; 0.05; 0.10) powders with a minimum content of secondary phases is 1060–1080 °C. While the synthesis procedures should be repeated not less than three times. An increase in the strontium content above 10 mol.% leads formation of significant amount of secondary phases such as $BaMoO_4$, $Ba_3Nb_6O_{13.5}$, and $Ba_4SrNb_4O_{15}$ due to reaching the solubility limit of Sr in $Ba_7Nb_4MoO_{20}$. The synthesized powders comprise particles with a rounded irregular shape and polydisperse size distribution spreading from 0.05 μm to 12 μm. The majority of the particles are within the 1.5–5 μm size range, while their average size is about 2.1 μm. Moreover, the size of the particles was found not to depend on the strontium content.

Acknowledgments

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Effect Of The Content Of Inclusions In Synthetic Diamond Powders For The Chenge Of Their Physico-Mechanical And Physico-Chemical Properties

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The use of effective abrasive tools that contain synthetic diamond powders (SDP) is an important direction for the development of the engineering industry. The size of diamond crystals, the number of inclusions in them and the strength characteristics depend on the growth rate of the crystals. Bulk defects of crystals affect the physico-chemical and physico-mechanical properties SDP and the operation of the tool. The aim of the work is to study the influence of the content of inclusions of SDP on the change of their physico-mechanical and physico-chemical properties. The powders of SDP brands AC6 grain size 160/125 80/63 system Ni-Mn-C were investigated. The powders were subjected to mechanical crushing and ultrasonic treatment, separation on R-20 sieves, separation in a magnetic field. Initial and new technology SDP were evaluated by grain composition, strength characteristics, coefficient of thermal stability, uniformity in strength, size, surface defect; abrasive ability, specific magnetic susceptibility. The study of the source SDP showed: the content of the main fraction is not less than 70%, homogeneity in size 17.7-25.7%, abrasiveness - 4.8-3.7 mg, heat resistance - 61-59%, homogeneity in strength - no more than 25%, the content of inclusions - 3,413-2,127 wt.%, the specific magnetic susceptibility - 22,3-11,5 10-8, m3 / kg. The use of new technology allowed to reduce the average grain size by 7-10%, increase the content of the main fraction by 4.3%, the coefficient of homogeneity of linear dimensions by 7-9%, develop surface (~ 10%), abrasive ability - by 6%, homogeneity by strength of 1.2-1.5 times, increase ~ 10 times the interval of specific magnetic susceptibility, 1.2 times the strength of the fractions. The content of inclusions 3,631-2,0143 wt.% The coefficient of thermal stability of powders of fractions with lower magnetic susceptibility is 1.8 times higher than that of fractions with higher magnetic susceptibility.

Electrochemical Synthesis Of Ultra-Fine Powders Of Tungsten Carbides

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Tungsten carbides occupy a significant segment of the global market for functional materials. The unique combination of physical, chemical and operational properties has made them in demand for widespread use in many industries. The method of high-temperature electrochemical synthesis is one of the most promising for the production of tungsten carbides powders with a high specific surface area, small particle size and provides the ability to make its doping by useful inclusions (e.g. Co, Ni, Pt) in one step while synthesis. Potentio- and galvanostatic electrolysis was carried out of the molten salt system: Na,K|Cl (1:1); $Na_2W_2O_7$ – 16,5 mass.%, Li_2CO_3 – 4,1 mass.%; pressure of CO_2 – 0,5 MPa. The synthesis temperature was 700–750 °C. The cathodic current density is 0.05 – 0.2 A/cm^2. The properties of the products were studied by XRD, SEM, TEM, Raman and BET methods. Cyclic voltammetry studies of the system Na,K|Cl–$Na_2W_2O_7$–Li_2CO_3–CO_2 have shown that the joint reduction of tungsten and carbon occurs from lithium complexes of tungstate and carbonate anions at potentials of ~ -1.1 – -1.3 V at the limiting current of carbon reduction from CO_2. It is established that the necessary condition for the stable production of monocarbide WC is the creation of excess CO_2 pressure. The current yield of the composite WC with free carbon (5 mas.%) was ~0.3–0.4 g/A·h. The obtained product is hexagonal WC with average particle size of ~10 nm and crystal lattice parameters a = 2.8953, c = 2.8384 Å. Indicated values are slightly different from the standard, that indicates the defect of the crystal lattice. It was found by the SEM and BET that carbide powders consist of hollow spherical mesoporous structures and have a specific surface area up to 140 m^2/g. The results obtained in this work exhibits that electrochemical synthesis is a fast, cost-effective and precisely controlled approach for the preparation of a dispersed tungsten monocarbides which can be used as an effective catalyst.

Effect Of Vacancy Swelling On Phase Changes In Nanocomposites Under Irradiation

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Under irradiation, highly dispersed composite materials (NDCM) are subject to risks of radiation-induced swelling and phase transformations due to the accumulation of defects. Objective is to substantiate the influence of vacancy swelling on the phase stability of dispersed inclusions in NDCM. A spherical Fe particle in an inert medium is chosen as the model system. Methodology. We analyse phase changes bcc Fe <–> fcc Fe depending on the particle size, vacancy swelling and parameters. The thermodynamic description is based on the calculation of the Gibbs free energy of Fe nanoparticle for phase states with vacancy-type defects and the energy barrier for new phase formation. The phase stability is measured from the point of view of competing energy factors: accumulated vacancies, the bulk energy of phase transition and the surface energy. Results. We found: (i) size dependence of phase transition of Fe nanoparticles on the vacancy swelling and (ii) the possibility of zones of radiation stability (tolerance) of Fe nanoparticles. Phase transition bcc-Fe –> fcc-Fe. For particles up to 2 nm, the transformation can occur without irradiation: the surface energy is the dominant component of the total energy; irradiation causes a phase transition. Particles with sizes from 3 to 9 nm have radiation stability due to superposition of compensating effects of the surface energy and the energy of vacancies. For particles larger than 3 nm irradiation causes a phase transition: the energy of vacancy defects dominates in the total energy. Phase transition fcc-Fe–>bcc-Fe. Particles up to 5 nm are stable, without radiation do not undergo a phase transition and in the presence of irradiation can transform with an energy barrier less than 50kT. For particles larger than 5 nm the transformation is possible only under irradiation: the energy of vacancy defects dominates in the total energy, but the energy barrier for new phase formation is more than 50kT.

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The Effect Of Cooling Rate On Structure And Mechanical Properties Of CoCrFeNiMnBe High-Entropy Alloy

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The first works related to designing and complex study of a new class of materials, i.e., the so-called high-entropy multicomponent alloys (HEAs) were published in 2004. As a rule, these compositions comprise 5–13 principal elements, the concentrations of which are close to equiatomic (5–35%). The HEAs are characterized by unique structures and many useful characteristics, such as hardness, wear resistance, resistance to oxidation, corrosion, ionizing radiation and high thermal stability. This work is dedicated to establishing the effects of the composition and the cooling rate on the structure, phase formation and microhardness (Hμ) of CoCrFeNiMnBe HEA in the as-cast and rapidly quenched state. The as-cast samples were prepared in a copper mold. A technique for liquid quenching (LQ) consisted of rapid cooling of melt drops upon their collision with the internal heat-conducted surface of a rapidly rotating (~8000 RPM) hollow cylinder. The estimated cooling rate was ~1000000 K/s. The analysis of the XRD patterns allowed us to establish that the investigated HEA in the as-cast state has a structure in which there is an FCC phase with lattice parameter a=0.3588 nm, BCC phase (a=0.2872 nm), and BeNi(Co) phase (a=0.2610 nm). At the same time, the LQ sample has a two-phase structure of the FCC phase with a=0.3599 nm and the BeNi(Co) phase (a=0.2610 nm). The microhardness in the as-cast state is Hμ=3400 MPa, while in the LQ state Hμ=5600 MPa. So, the addition of Be significantly improves the mechanical characteristics of the studied HEA as compared with the original Cantor alloy (CoCrFeNiMn). The fact that the LQ HEA of the Co-Cr-Fe-Ni-Mn-Be system is characterized by higher values of Hμ than as-cast alloys is not unexpected, since the microstructure and the phase composition of the as-cast alloy after decomposition are in a more equilibrium multiphase state, while LQ alloy yields a higher level of microstrains, dislocation density and smaller grain sizes.

Electrochemical Synthesis Of Ta2Si From Chloride-Fluoride Melts

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Tantalum silicides: Ta3Si (Tm = 2613 K), Ta2Si (Tm = 2783 K), Ta5Si3 (Tm = 2833 K) and TaSi2 (Tm = 2313 K) belong to refractory compounds. In the series of refractory compounds, silicides are distinguished by a high chemical stability at high temperatures; therefore, they are widely used as protective materials in the chemical industry. Thanks to semiconductor properties and thermal stability, tantalum silicides promise much as a substitute for silicon in electronic technology.The possibility of the electrochemical synthesis of tantalum silicides in chloride-fluoride melts is examined. Based on thermodynamic calculations, the possibility of electrochemical synthesis of tantalum silicides from chloride-fluoride melts has been assessed. It has been shown by voltammetric studies that the process of electrochemical synthesis occurs in one stage. Tantalum silicides as powder and coatings with the stoichiometry Ta:Si = 2:1 have been obtained by electrolysis. The stoichiometry of the cathodic product was independent of the ratio of tantalum and silicon ions in the melt. Only Ta2Si can be obtained by the electrolysis of the NaCl-KCl-K2TaF7-K2SiF6 melt at 973 K regardless of the electrolysis conditions (current density, electrolyte composition).

Possibility Of Manufacturing High-Entropy Alloys On The Basis Of Ferro-Alloys

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The vast majority of HEAs created to date are made of pure metal elements and contain significant quantities of such high-value and scarce elements as Co, W, V, Nb, Mo, Ta, etc., which significantly narrows economic feasibility their practical application. Therefore, the aim of this work is to create a new high-entropy alloy, based on inexpensive and common ferroalloys and nickel (Ferrochrome (FH800) – Ferrotitan (FTi70) – Ni), study of its phase and structure, as well as determine its mechanical properties. In the process, a fundamentally new approach to the choice of components of high-entropy alloys was implemented. Alloys were made from mixtures of ferroalloys with a high content of Cr and Ti, as well as with the addition of Ni. Prototypes of FH800-FTi70-Ni alloy (chemical composition – TiCrFeNiC) were made. Peculiarities of their structure, phase composition and properties have been studied. These materials were chosen due to their low cost, high prevalence and availability. The investigated alloys were made by hot forging (HF). In general, the phase composition of the alloy FH800-FTi70-Ni (without annealing) is represented by four phases. BCC and FCC solid solutions, cubic carbide (TiC type) and intermetallic with Ni3Ti type structure are formed in the sample. However, intermetallic is not thermodynamically stable and disappears after annealing at 1000 °C. An increase in the annealing temperature leads to a decrease in the amount of BCC phase component and an increase in the amount of cubic carbide, compared with the sample without annealing, due to the intensification of carbide formation during annealing. The mechanical properties of alloys were determined by the method of automatic indentation at an indenter load of 1,5 N, according to which the yield strength of alloys σs is more than 3 GPa, and the hardness, determined on the hardness tester TK-14-250 is more than 60 HRC.

Finite Element Simulation Of Temperature Field During Electron Beam Sintering With Rotation

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The field of temperature gradient is quite important factor for sintering process of powder compacts. It is especially important when sintering of refractory materials is provided in non-equilibrium conditions of high-speed heating using electron beam energy. Previously, we presented the results of numerical simulation by the finite element method of the temperature field during sintering of molybdenum powder blanks for conditions of stationary electron beam heating. The aim of this work was to simulate the evolution of the temperature field under the action of an electron beam in a rotating sample. The task was solved as a problem of nonstationary thermal conductivity using the finite element method. As the environment for simulation, we used ANSYS Workbench 2021 R2 Academic edition software. We calculated temperature field in cylindrical specimen with horizontal rotation axis. At time 1/12 of the sample surface was subjected to electron irradiation. The exposure time corresponded to different speeds of rotation of the sample from 0,5 to 2.0 s-1. The following results were obtained from simulation. The temperature field is determined by the heating power, the rotation speed of the sample, the thermal conductivity of the material and the coefficient of radiation of the surface. The temperature field rotates with the sample. The temperature along the axis of rotation rises quite smoothly. The maximum temperature is observed on the surface of direct exposure to the electron beam, while minimum temperature - on the surface that has passed the path about 270° after direct exposure to the beam. The difference between the maximum and minimum temperature decreases with increasing rotation speed from 470°C at 0.5 s-1 to 300°C at 2.0 s-1. The average temperature of the sample, in this condition, increases by 40-60°C.

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Thermophysical Properties Of ZrO2-based Ceramics Doped With A Mixture Of Yttrium-Subgroup Rare-Earth Metal Oxides

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Thermal barrier coatings (TBCs) are widely used in the hottest sections of gas turbines engine (GTE) blades in order to increase of operating temperatures for better engine performance and efficiency while enhancing component durability. A ZrO2 stabilized by 6–8 wt. % Y2O3 (YSZ) is a state-of-the-art TBC ceramic material. However, its application temperature is limited by 1200 ºC. Since the operating temperatures of next generation high-power GTEs are increased to 1500–1600 ºC, the development of new ceramic topcoat materials with lower thermal conductivity becomes highly relevant. The objective of this research is to measure the thermal conductivity of new ZrO2-based ceramics doped with a heavy concentrate (HC), consisting of (wt.%) 33,2 Dy2O3; 21,8 Er2O3; 13,3 Y2O3; 12,5Yb2O3; 8,9 Ho2O3; 1,86 Tm2O3; 1,22 Tb4O7; 0,57 Lu2O3; and 6,65 - other oxides (including 3,2 Al2O3). The studies of thermal conductivity of the 70-90 wt. % M-ZrO2–30-10 wt.% HC sintered pellets were carried out for the first time in interval 313-673 K in the monotonous heating mode using the dynamic calorimeter method. It has been shown that the thermal conductivity of such ceramics will decrease when the doping content of HC is increased due to the scattering of the phonon via forming oxygen vacancies and defect clusters. Among investigated samples, the 70 M-ZrO2–30 HC composition demonstrates the lowest thermal conductivity, which was 50 % lower than that of the standard 6-8 YSZ. The specific heat temperature dependences of ZrO2-based ceramics with a different HC content were calculated according to the Neumann–Kopp low for the first time and then that was used for thermal conductivity computations. In conclusion, the addition of cheap complex stabilizers, which are a mixture of mainly oxides of rare earth elements, can be a viable strategy for further reducing the thermal conductivity of ZrO2-based ceramics and creating new TBCs.

Influence Of Habitus Of Large Tungsten Microcrystals On The Features Of Their Carbonization

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The process of carburization tungsten microcrystals and the quality of the obtained carbide particles can be controlled by temperature, isothermal holding time and carbon concentration in the environment [1]. However, how the habitus of tungsten microcrystals will affect the carburization process has not yet been considered. Microcrystals of tungsten of different habitus can be obtained formed from faces corresponding to indices (110), (100), (211) for a BCC lattice [2]. Each face has its own surface energy. According to [3] the face (110) has the highest surface energy — 0,711 J/m2, slightly less (100) – 0,432 J/m2, even smaller (111) – 0,242 J/m2. During carburizing large tungsten microcrystals from the gas phase, it should be expected that the carbide phase nuclei will be formed first on the face (110) then on (100) and practically not on (211). The specific surface of the carbide-forming faces of the microcrystal formed only by the faces (110) will be the largest. Such a microcrystal is a rhombododecahedron. The smallest specific surface of carbide-forming faces will be in the polyhedron formed by all three planes. To observe the places where the nuclei of the new carbide phase begin to form, use large tungsten microcrystals where the faces predominate (110). We carried out carburization at a temperature of 1100°C with a methane content of 2% (vol.) in a hydrogen environment for 120 min.As a result of comparing the surfaces of the original tungsten microcrystals before and after their carburization, it was found that at a given temperature and isothermal holding time single nuclei of a new carbide phase are formed on the face (110) and not on the face (211). In our opinion, to obtain homogeneous grain sizes of carbide particles, it is necessary to use microcrystals formed by the face (110). To obtain grain sizes of carbide particles with a wide distribution, it is necessary to use tungsten formed by all three planes (110), (100), (211).

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Fine structure of intericosahedral atomic chains in boron carbide doped with silicon and aluminum

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Doping of boron carbide with silicon is considered among the most promising ways to improve its performance in conditions of high mechanical stress [1], presumably through the mitigation of amorphization. Recently aluminum has been extensively explored at IPMS NAS of Ukraine as an alternative dopant, with promising experimental results on the resulting composites. In this work, we assess the possible direct influence of boron carbide doping with Si and Al on basic mechanical characteristics (bulk and Young's moduli) and look in detail at the effect of both dopants substitution into the intericosahedral chains on the fine structure of the chain, which seems to be the determining factor of amorphization mitigation. The mechanical moduli were calculated using the thermo_pw sub-package of Quantum Espresso DFT code. An in-house program was developed with Python and ASE to model the structure with various radial displacements of dopant atoms in the chain from the linear position. Total energies of the displaced configurations were calculated with Density Functional Theory (Quantum Espresso), and further structural optimization was done for the lowest energy candidates. The results show that in both Si and Al cases, there is no activation barrier between linear and angular configurations, and the latter has lower energy. Thus, doping into the chain is expected to always change the chain configuration to angular. Such a change leads to dipole formation, and complex dipole-dipole interactions will significantly influence the formation energy of the doped boron carbide. The optimal radii of displacement are 0.78 Å for Si and 0.94 Å for Al in directions coplanar with C-B bonds of the edge carbons in the chain. The configurations are degenerate and are the best candidates to be assumed in dipole ordering. The structural influences of the Si and Al come out as similar and technological factors determine the application of one or the other for amorphization mitigation.

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FILMS AND COATINGS

Role of interfaces in strength enhancement of superhard nanocomposite coatings

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We give the review of the recent studies on superhard nanocomposite coatings and the role of the interfaces in them. An accent was put on the nanocomposite and nanolayered systems based on transition metal (TM) compounds with the amorphous and crystalline ceramic interfaces. We also focus on the first-principles models of the interfaces. The following systems were considered: TMX/SiY, X, Y = C, N; TMN/AlN, TMN/BN and TiB2/(BC, BN, AlN, SiC). Experimental results were comprehensively investigated and the effect of interface structures on the mechanical properties was analyzed. Several theoretical models of the heterostructures with the one-layer and multi-layer interfaces were considered. It is shown that the epitaxial ceramic interfaces can be formed between constituent phases provided they will be dynamically and mechanically stable. This criterion is used to predict temperature-induced structural transformation of the interfacial layers. Also, such an approach enabled one to explain the formation of the epitaxial interfaces in a number of nanolayered coatings based on TM nitrides. An analysis of the calculated stress-strain relations of different heterostructures showed that ideal tensile and shear strengths of the nanocomposites should be lower compared to those of the constituent TM compounds. It follows that the main role of the interfaces in strength enhancement of nanocomposites is to impede the dislocation movement and crack propagation. The blocking effects on the dislocation motions decrease with the transformation of the epitaxial or hetero-epitaxial layers into amorphous ones. The amorphous interface can also act as an obstacle for dislocation motion however its impeding effect on the dislocation motion is much smaller than that of the coherent interfaces.

NEWLY-DEVELOPED FUNCTIONAL NANOCOMPOSITE MULTILAYER COATINGS BASED ON TRANSITION AND REFRACTORY NITRIDES: ADVANTAGES AND LIMITATIONS

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Over the last few decades, intensive development of modern technologies has stimulated the need to improve the protective properties of materials that have multifunctional industrial usage. Enhanced hardness, service life, resistance to wear and oxidation are among the list of the essential properties that these materials must possess. Particularly, multilayer structures fulfil these characteristics. Herein, we will discuss the advantages and limitations of microstructure and functional characteristics of newly-developed functional nanocomposite multilayer coatings based on transition and refractory nitrides. In order to highlight characteristics of transition and refractory nitrides, we consider modern nanocomposite multilayer coatings, in particular, TiZrN/TiSiN, TiSiN/NbN and WN-based modified with TiN and (TiSi)N layers. All experimental coatings were deposited by the vacuum arc technology and studied with respect to the stability of the structural and mechanical properties using widely applied methods. The generalized results of the investigation are the following: TiZrN/TiSiN coatings demonstrate the coherent growth; the crystal structure is defined with fcc-(TiZrN||ncTiN+a-SiNx) relation; the hardness and elastic modulus increase up to 38.2±1.15 and 430±12.9 GPa, respectively; adhesive, oxidative and abrasive are the main wear mechanisms; TiSiN/NbN coatings are II-phase cubic structures with a preferential orientation along (200)TiN and (00.2)NbN-δ’; the lattice parameter for TiN indicates the formation of compressive stresses; the hardness increases up to 40 GPa with decreasing bilayer period to 10 nm; as-deposited WN coating consists of WN-β phase, while the multilayer WN/TiN and WN/(TiSi)N coatings are composed of c-TiN and WN-β; the heat treatment doesn’t fundamentally change the phase state, but lead to growth in the crystallite size and relaxation of internal stresses; heat treatment increases the hardness by 6–7%. Thus, all newly-developed coatings are durable materials and have good strength characteristics even after heating and can provide an increase in the productivity of cutting materials, tools, and machine tools.

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Coercive Force Of Magnetically Sensitive Fe, Co, Ni / Gd_2O_3 Nanostructures

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In nanoscale film structures consisting of contact layers of iron groups Fe, Co, Ni and REM oxide, due to the exchange f-d interaction between atoms with unfilled f and d electron shells, there is an ordering of the magnetic structure of ferromagnetic metals, thereby increasing many dependent from it, properties: galvanomagnetic, magneto-optical, and others. Estimation of the possibilities of amplification of these properties in the mode of high frequencies of remagnetization of nanostructures is revealed when considering coercive force as a characteristic equal to the magnetic field required for demagnetization (i.e reversal) of matter. A significant increase in H_c, in the presence of exchange f-d interaction, would reveal the impossibility of using the achieved gain of magnetization and its dependent properties at high frequencies. The aim of this work is to estimate the H_c in Fe, Co, Ni nanofilms before and after the application of the REM oxide layer, i.e before and after the occurrence of f-d interaction, which enhances the magnetization of the metal layers. The value of H_c was estimated from the hysteresis loop describing the curve of the field dependence of the resistance of the ferromagnetic metal RH, proportional to the magnetization, M on the magnetic field B when measuring the anomalous Hall effect. Comparing the values of Hc obtained in Fe, Co, Ni films before and after applying a 100 nm thick Gd_2O_3 film, it was shown that after applying the REM layer, Hc increased in Ni films from 0.08 to 0.1 kOe; Fe from 0.8 to 1.0 kOe; Co from 1.0 to 1.6 kOe. This increase is insignificant.

On Nonlinear Mechanisms Of The Formation Of Protective Films In The Oxidation Of Nickel Alloys Alloyed With Refractory Metals

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The technology of powder blanks consolidation by reactive sintering, developed at IPM NAS of Ukraine, makes it possible to distribute evenly nanodispersed inclusions of Y2O3[1]. During reactive synthesis, the powder system loses hereditary structural defects of the powder body, which leads to an increase in plasticity, impact strength, heat resistance and fatigue strength[2]. Irreversible processes during reactive sintering with a characteristic nonlinear interaction also appear during the operation of materials at high temperatures and in active media. It is the processes of interaction of active gases that define the heat resistance of the material, which determined the purpose of the work. Due to the non-linear nature of the oxidation of alloys, especially with the main alloying metals of IVA-VA groups and Cr, the existence of several kinetic trajectories of the development of the process and the formation of one or another protective film is possible. Therefore, when studying standard nichrome with 20% Cr, the phase composition of the protective film was studied depending on the Al content. Threshold values of its concentration are found, at which the composition of the oxide layer changes qualitatively and quantitatively, which confirms the non-linear character of oxidation. At a content of 5.7% Al, the film of oxide layer consists mainly of Cr2O3, and at 6%Al, it is represented by oxide Al2O3. At the limiting concentration of alloying elements (Ti, Nb, Mo and W) in the region of the existence of solid solutions, the alloys lose their heat resistance. The limited addition of these metals with an Al content of about 8% in the alloy has a positive effect on the heat resistance of the material. During the cyclic oxidation of alloys with the limiting concentration of the existence of a solid solution at high temperatures, the formation of unstable nickel oxides is observed. The results obtained testify to the need to create a dynamic theory of heat resistance.

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HEA–Ceramic Composite Coating Deposited By Cold Spraying

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Cold spraying (CS) is a promising technology for applying a variety of coatings, allowing the deposition of almost any material in their initial phase and structural states [1]. One of such materials are high entropy alloys (HEA) with their unusual properties [2, 3]. At the same time, studies show that HEA consisting composite materials exhibit higher characteristics [3]. Therefore, the aim of this work is to study the process of coating deposition using composite AlNiCoFeCr–TiB2 powder as a feedstock. The feedstock for the deposition was "70 wt. % AlNiCoFeCr HEA – 30 wt. % TiB2" powder prepared by blending in a planetary mill for 2 hours at a rate of 250 rpm. Deposition was performed using the cold spray low pressure system DYMET 405 at a minimum temperature of 200 °C in the pressure range from 0.7 MPa to 0.9 MPa. XRD, EDX and microstructural analyses were carried out on the obtained coatings. The results of XRD and microstructural analyses showed that the phase composition and nanostructural state of the initial powder are preserved in the CS coatings. However, the obtained data indicate a different content of TiB2 solid particles in the feedstock powder and CS coatings, especially on their surface. Indeed, as the pressure increases, the TiB2 content in CS coatings increases, approaching to the feedstock level. In addition, with the increase of pressure the thickness of the coatings increases by 4-5 times and become close to 200-250 μm. At the same time the spraying of pure HEA powder at the similar temperature even at the maximum pressure of 0.9 MPa allows to obtain the coating thickness of only 20-50 μm, while hard TiB2 particles cannot be sprayed. Thus, the use of composite materials with hard TiB2 and soft HEA constituents considerably increases the intensity of deposition even at low values of temperature and pressure, which represents a broad perspective for such materials and, therefore, requires further research.

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Extending Application Limits Of Yttrium-Stabilized Zirconia In Thermal Barrier Coating Application

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Yttrium-stabilized zirconia (YSZ) has been the state of the art for thermal barrier coating (TBC) applications in gas turbines for several decades. Although the material has unique properties, some critical degradation processes arise when temperatures exceed ~1200°C. Further improvement in gas turbine efficiency by increasing the temperature requires the avoidance of detrimental impact from phase transformations, increased sintering and attack from aggressive silicate deposits (CMAS). Gas burner test rigs are used to investigate the degradation behavior of plasma sprayed YSZ TBCs under gradient conditions. Here, surface temperatures, cooling rates and the deposition rate of silicate deposits are varied. In addition to the spallation lifetime of the TBC layers, the microstructure and phase composition of the TBCs as well as the infiltration behavior of the slags are characterized by SEM and X-ray analysis. It was experimentally shown that under typical cycling conditions, it is not primarily the time at elevated temperature that leads to reduced life, but the high transient cooling rates. At reduced cooling rates of 10K/s, TBC systems could be operated at a surface temperature well above 1500°C with no reduction in life in the burner rig test. The reason is believed to be the reduction of peaks in the energy release rate during rapid transient cooling in combination with phase evolution. The corrosion tests indicate that the infiltration as well as the kinetics of degradation in the gradient condition are mainly influenced by the wetting behavior of the molten CMAS compounds. While the Young's modulus of the TBC correlates closely with the degree of CMAS infiltration, the chemical interaction of YSZ with CMAS does not seem to have an immediate effect on the structure and density of the internal surfaces. This enables optimization of the TBC microstructures for prolonged life.

Ceramic-Spinel Composite Layers As Effective Materials Used As Protective Interconnector Materials In Solid Oxide Fuel Cells (SOFCS)

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High-temperature corrosion of steel interconnects is one of the important challenges to obtain high-performance cells with a very long lifetime in excess of forty thousand hours. The research conducted so far focuses on the well-known manganese-cobalt spinel, which is difficult to recycle and also carcinogenic [1]. In this work, we describe a new material in the form of manganese-iron-copper spinel and its protective, electrochemical, and structural properties [2]. Spinel was synthesized using a modified Pechini method. The thin, reactive element (RE) ceramic layers were applied to the steel plates by an electrolytic technique. On top of the thin RE layers, a thicker Mn-Cu-Fe spinel layer was prepared by electrophoretic deposition (EPD). Thermogravimetric measurements were made by cyclic high temperature oxidation with controlled weight gain. Structural studies were performed using X-ray absorption spectroscopy (XAS) and X-ray diffractometry (XRD) measurements as well as electrical measurements were performed. Additionally, a images were taken using a Scanning Electron Microscope (SEM) supplemented by energy-dispersive X-ray (EDX) analyses. The combination of a thin RE layer with a thicker spinel layer is responsible for blocking outward chromium diffusion, reduction of the weight gain of the sample in relation to the sample with the spinel alone, and in relation to the reference samples. In addition, the use of composite layers changes the structural properties of the material itself, as shown by XAS studies and analysis by means of surface and cross-section images made with SEM and EDS analysis. The use of RE-spinel layers allows for a significant improvement in oxidation properties, and the spinel itself perfectly replaces the commonly used manganese-cobalt spinel. It has been proven that the use of a ceramic layer has a beneficial effect on weight gain, which has an impact on the efficiency of interconnectors and the operation of the entire SOFC system.

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Structure And Wear Behavior Of FeNiCrBSiC–MeB2 Electro-Spark Coatings

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In this study the effect of MeB2 additives on the structure and wear-behaviour of electro-spark coatings based on the commercial self-fluxing alloy (FeNiCrBSiC, FTB20 (FeNiCrBSiC–20%(мас.)TiB2), FCB20 (FeNiCrBSiC-20%(мас.)CrB2)) is investigated. The FeNiCrBSiC coating is characterized by thickness of 70 μm and globular surface as well as the FTB20 and FCB20 coatings represents uniform and relatively smooth layers of 50 μm in thickness. Microhardness values do not vary along the coatings thickness and are within the range from 10 up to 14 GPa. Chemical compositions of electrodes and electro-spark coatings are the same which notice the absence of mixing the electrode materials with steel substrate. However, the structure of FeNiCrBSiC, FTB20 and FCB20 electrodes and coatings differs significantly due to the refinement of hard chromium and/or titanium borides and carboborides in the electrosparking process from 20-25 μm up to 1 μm in size. The heterophase structure of electro-spark coatings consists of a nickel-iron based matrix and fine reinforcing particles of chromium and/or titanium borides and carboborides. The effect of speed and load on the wear rates of coatings is studied under dry sliding conditions. Wear rates of the FeNiCrBSiC, FTB20 and FCB20 electro-spark coatings decrease while that of WC-6%Co increase when speed rises form 4 up to 12 m/s. The wear rate values of coatings greatly increase with the increasing load from 0.1 up to 0.4 MPa. Investigation of friction surfaces revealed that wear of FeNiCrBSiC coating is caused by the destroying of globulars, while wear mechanism of FCB20 coating is associated mainly with brittle crushing of alloyed layer. The FTB20 coating has 2-3 times higher wear-resistance as compared to FeNiCrBSiC coating.

Improving The Service Life Of Firearms Barrels By Pulse-Plasma Nitriding

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The desire to increase the service life of firearms barrels causes a lot of research and technical proposals, such as the usage of special steels, heat treatment and deposition of wear-resistant coatings.Analysis of the wear types that are present in automatic weapons barrels showed that reaching the limit state of operation is caused by the number of processes that violate the continuity of the barrel surface as a whole. The aim of the work was to strengthen the barrels of firearms by pulse-plasma nitriding. A promising direction for controlling the structure and performance properties of the barrels' internal surfaces is the pulse-plasma technology usage. It is based on the combination of pulsed discharge for the creation of plasma flow of elements - diffusants and pulsed displacement of substrate potential for ion implantation or surface modification with the transition to a batch-pulse mode of induction discharge excitation, which is new and original. Experiments were carried out on tubular specimens made of 40XH2MA steel, which served as an empty cathode with an inner diameter of 12 mm and a rod anode located in the middle. To implement the process, the ion-plasma unit VU-1B was modernized by equipping it with a modulator of high-frequency pulses. Usage of the pulse mode with a frequency of 10-15 kHz provides stability of diffusion surface saturation process without electric breakdown and arc formation. The pulses duty cycle plays an important role in this process, a decrease of which leads to localization of plasma volume in the tubular sample. As a result of pulse-plasma treatment in a gas mixture of nitrogen and argon, the microhardness of the inner surface increased from 2 to 5 GPa and the relative wear resistance increased 2-4 times. Thus, it is advisable to use pulsed plasma nitriding in high-frequency glow discharge plasma to strengthen the inner surface of barrels.

Formation Of Composite Layers By Ultrasonic Impact Treatment Of Cu–39Zn–1Pb Brass Using Reinforcing Particles Of Silicon Carbide

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The structure, phase composition and mechanical properties of composite coatings synthesized by ultrasonic impact treatment (UIT) of the surface layers of two-phase Cu-39Zn-1Pb brass with the addition of reinforcing SiC particles of different fractions, i.e. 3–5 μm, 14–20 μm, 40–50 μm, 80–100 μm, 160–200 μm, were studied. Owing to severe plastic deformation caused by UIT, there is a partial grinding and embodiment of the SiC powders into the near-surface layers of brass. The proposed approach allows synthesising the high-strength composite coatings with a thickness of ~50 μm. The maximum hardening effect due to the maximum crystallites' (CSA) refinement of the phase components of brass is achieved under conditions of reinforcement with the SiC powder with a particle size of 160–200 μm. Application of the SiC powder fraction of 40–50 μm gives the best result in terms of the minimum CSA size of the SiC powder and its higher volume fraction and more uniform distribution in the surface layer (EDX analysis shows minimum contents of Zn and Cu, and maximum contents of Si and carbon). Despite the fact that the microhardness of such a coating is slightly lower than those for the UIT-produced composites with the powders of larger size, the integrity, homogeneity and uniformity of the composite coating formed are maximal in this case.

Deposition And Characterization Of Layered Ti-B-C Films

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In recent years the efforts of researches have been directed to development and investigation of the properties of multilayered coatings which are composed of sequential layers of two different materials. Such approach is one of the most universal and prospective ways in creating materials that are suitable for application in various fields of engineering. Nanolayered Ti-B/C films were deposited in the unit equipped with two magnetrons using commutator which enabled alternating sputtering of two targets. As substrates were the silicon platelets to which negative bias voltage (50 V) was applied. Before films deposition the substrates were pre-heated up to 400oC. The work parameters at TiB2 target were unchanged whereas at the graphite target the sputtering current varied in the range of 50-200 mA. Earlier [1], we have investigated the nanocomposite Ti-B-C films deposited by simultaneous sputtering of TiB2 and graphite targets and draw a conclusion that in the those Ti-B-C films definite portion of boron atoms can be substituted by carbon ones in the TiB2 lattice. As a result the solid solution TiB2-xCx forms in the film. Based on similarity of the results of XRD and XPS investigation we draw a conclusion that the nanolayered Ti-B/C films obtained in present work are a sequence of nanocrystalline layers of TiB2-Ti(B,C)2 and amorphous carbon layers. The Knoop hardness was shown to increase up to maximum value of 37.5 GPa and then decrease with increasing of the sputtering current at the graphite target. So, there is an optimum Ti-B-to-C layers ratio at which the hardness is at a maximum. Tribological properties of Ti-B/C films improved with increasing sputtering current at the graphite target due to increasing thickness of amorphous carbon layer.

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Interactions Of Atomic Hydrogen With A Metal Coated With An Oxide Film

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High-strength aluminium alloys of the following system: Al-Mg,Al-Li,Al-Be, Al-Cu-Mg,Al-Cu-Mn,Al-Zn-Mg-Cu are often used as construction materials for airspace technique. Atomic hydrogen produced in dissociation of molecular one on the surface of the oxide film penetrates through these defects. Atomic hydrogen diffuses into the metal lattice and forms either the solid solution of hydrogen in metal or hydride. One of the mechanisms for interaction between atomic hydrogen and the metal covered with an oxide film. It was found that atomic hydrogen passed through the protective surface film, dissolved in metal and recombined on the grain boundaries, voids and other irregularities in crystals. If hydrogen pressure reaches a critical value, one can observe hydride formation. It leads to hydrogen embrittlement of material and its destruction. Conclusion: 1.Considering the fact that in the products from the aluminium alloy hydrogen may pass hereditarily in crystallization from the liquid state, it is necessary to assess its content by the method separating surface hydrogen and hydrogen dissolved in the bulk. 2.Hydrogen may be absorbed by the aluminium alloys containing the hydride forming metal: Sc,Mg,Li,Ti,Zr as their component. Many of them dissolve in initial aluminium and form α-solid solution. But at the content higher than the solubility point, and at recrystallization or age hardening the individual aluminides may reject, for example, Al3Sc,Mg2Al3,LiAl which form friable hydrides. It is also necessary to conduct testing in the medium of atomic hydrogen and at proton bombardment. 3.A high-pressure container made of Al-Mg for a hydrogen accumulator was made. Developing an understanding of the processing of alloys is an important research direction, thanks to which Shuttles and aircraft can be manufactured, but also modern containers for hydrogen storage. Problem of transportation and storage of hydrogen for hydrogen energy is in the first place!

Microstructure And Hardness Of Borides-Containing Layers Obtained By Laser Alloying Of Additively Manufactured 18Ni-300 Maraging Steel Part Surface

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Maraging steels (MSt) are known as a special class of high-strength steels possessing a superior combination of mechanical and technological properties. However, MSt have only moderate hardness and insufficient resistance to abrasion wear, that limits parts longevity and wider application of MSt. Nowadays, MSt are very demanded in a field of additive manufacturing (AM). The present work suggests surface laser alloying to improve hardness of MSt parts manufactured by AM. Concept Laser M3 equipment was used to produce samples from 18Ni-300 MSt powder. For the surface alloying, 1 kW CO_2 laser was applied at 0.5–4.0 mm laser spot and 250–1500 mm/min laser operating speed, providing 50955–796 W/cm² power density and 24.0–4.0 J/mm heat input, respectively. Before laser processing, surfaces were covered with amorphous boron paste. For the characterization of obtained layers, optical microscopy, XPS, XRD, and SEM/EDS techniques were applied along with Knoop hardness measurements. The appropriate melt pool geometry was obtained at 0.5 mm laser spot, providing ~84–184 μm melt pool depth. For these samples, XPS analysis revealed an increase in boron concentrations from ~3.1 to ~5.7 wt. % with a laser speed increase from 500 to 1500 mm/min. XRD analysis revealed prevailing of Fe_3B type borides along with the presence of FeB and Fe_2B type borides, austenitic and martensitic phases. The microstructure of laser-boronized layers showed evolution from fine dendritic microstructure, consisting of boride-based eutectic and Fe-based solid solution and having ~630–780 HK0.2 hardness (500 and 750 mm/min laser speed), to superfine lamellar nanoeutectic (~1000–1030 HK0.2; 1000 and 1250 mm/min) and further to submicron-sized grain boride structure (~1770 HK0.2; 1500 mm/min). The obtained hardness was up to three times higher than that of MSt after aging (~600 HK), indicating that laser boronizing technique may be promising in term of the improve of MSt wear resistance.

Sputtering Of Compositions From Ir, Os And W With Nitrogen Ions And Back-Scattering Of The Ions From The Surface: Monte Carlo Simulation

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Ion sputtering is used in the production of thermionic cathodes coated with platinum group metals for high-power electronic devices. The sputtering with nitrogen ions instead of the commonly used heavy argon ions leads to improvement of the device characteristics, but data on the sputtering coefficients of these metals with nitrogen ions are extremely scarce. The purpose of this work is to estimate by calculation the coefficients of sputtering with nitrogen ions of compositions containing Ir, Os and W. The back-scattering of ions was also studied. To achieve this goal, the kinetic Monte Carlo modeling of the sputtering by atomic nitrogen ions with energy of 0.5–2.5 keV have been carried out with the program code TRIM that gives good agreement with experiment. The simulation of cascades of collisions of ions and recoil atoms with target atoms used the approximation of binary collisions of the fast particles with target atoms. The sputtering coefficients of the said metals in our ion energy range were 03–1.2. Calculations for different target compositions gave partial sputtering coefficients of composition components. In the calculations, the presence of the potential barrier on the surface was considered. This barrier was determined by the surface binding energy corresponding to the sublimation energy of the target material. For the multi-element targets, the surface binding energy was used as an arithmetic average of the sublimation energies of all target elements. The distributions of ion penetration depth into targets were determined; the average depths were tens of Angstroms. The back-scattering coefficients of fast neutral atoms N (former bombarding ions) from targets were determined; they were rather high, up to 40 %. These atoms had energy that reached 30–60 % of the energy of the bombarding ions. So, the back-scattering atoms strongly effect on properties of metal films on substrates.

Development Of Method For Extended Control Of The Electrospark Deposition Process

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The properties of electrospark coatings depend on a number of the deposition process parameters. Among them are the electrical parameters of the discharge, the size of the interelectrode gap, the state of the treated surface. Some of them are constantly changing during the deposition. Therefore, an important task is to develop methods for continuous control of the deposition process. The following control parameters are selected for continuous recording: the current-voltage characteristics of the spark discharge, the temperatures of substrate T1 and electrode T2, the force of the spark discharge acting on substrate F1 and electrode F2. The measurement results were recorded on a computer using an analog-to-digital converter. The coatings were characterized by deposited mass and wear resistance of the obtained layers. The dynamic parameters of cathode processes change significantly during the treatment. Reliable control of the deposition process is effective at the primary stage, lasting up to 40 seconds. A longer treatment leads to a sharp increase in the substrate temperature and an unregulated change in the control parameters. The relationship between the energy of cathode jets and the temperature of the substrate has been established. This makes it possible to operate the structure of coatings by controlling the substrate heating. The correlation in the wear resistance of coatings with the thickness of the deposited layer and the deposition parameters has been studied. A decrease in the wear resistance of the material with the coating thickness growth was found. A significant influence of the spark discharge force F1 on the coatings wear resistance has been established. Control of the deposition duration and the parameter F1 allowed to greatly increase the rate of electrode material transfer and to obtain the wear resistance of the coating exceeding the wear resistance of the sintered electrode material WC-6%Co for thin deposited layers (h<10 μm).

Study Of The Vortex Motion Of Electrolyte During The Electrolytic Deposition Of Nickel In An External Magnetic Field

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The influence of the magnetic field on electrolysis, corrosion and other aspects of the interaction of metal surfaces with electrolytes attracts much attention nowadays. Earlier the effects of a significant acceleration of corrosion of metals in electrolytes in a constant magnetic field and the emergence of multi-vortex structures in electrolytes under the influence of a constant magnetic field were observed. Electrodeposition of metals has been successfully used to create surfaces with desired properties. Magnetoelectrolysis is one of the most promising directions in this area. The use of a magnetic field allows obtaining both a "branched" fractal surface structure and a structure with improved smoothness and reflectivity. We observed and analyzed the vortex motion of the electrolyte during the electrolytic deposition of nickel on a ferromagnetic mesh electrode in an external magnetic field. The characteristic frequencies of rotation of the electrolyte were found by optical methods developed by us earlier [1]. This rotation is in many aspects similar to the processes occurring during the dissolution of a steel ball in nitric acid in a magnetic field. The calculated spectrum shows maxima corresponding to the characteristic frequencies of the electrolyte motion. The most intense maxima correspond to the frequencies of 0.161 Hz, 0.337 Hz and 1.113 Hz. The presence of clearly pronounced maxima shows that the motion of the electrolyte is ordered, cyclical, and not chaotic. The proposed method, with some modifications, can be used to study the frequency characteristics of the motion of liquids, gases and small objects without directly affecting the medium under investigation.

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Effect Of Plasma Thermocycling Nitriding Surface Modification On The Microhardness And The Wear Resistance Of 18HGT Steel

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The use of external fields for the processing of new materials has seen renewed interest in recent years. The surface hardening of steels and alloys using plasma nitriding is an efficient and reliable technique that can be used in the manufacturing and machining industries primarily to treat engine components, machine tools as well gears [1]. The effect of plasma nitriding treatment on the microhardness and wear resistant of 18HGT steel was studied. Nitriding has been carried out using pulse DC glow discharge in an atmosphere of a 25% N_2 and 75% Ar mixture. Microhardness results were obtained using a Vickers microhardness tester. The wear tests were conducted using a block-on-ring arrangement. The dimension of the block specimens was 20×10×5 mm^3. A plain carbon steel ring with an outer diameter of 40 mm and a width of 10 mm was used as the counterpart. At the end of each 30-minute test, the mass loss was measured. The study deals with modeling changing microhardness and wear resistant after plasma nitriding treatment. The central composite rotatable design of the second-order was found to be the most efficient tool to establish the mathematical relation of the response surface using the smallest possible number of experiments. According to our previous experiences, the predominant factors, which have a significant influence on microhardness, were identified. They are chamber pressure (50-100 Pa), temperature (450-550 °C), and duration of the nitriding process (3-9 h). Microhardness and mass loss were assessed as the second-order polynomial functions of the input process parameters. The obtained mathematical model contributes to the understanding of the effect of nitriding treatment parameters on microhardness and mass loss. The improvement of wear resistance for plasma-nitrided 18HGT steel is the result of a combination of microstructure and higher microhardness.

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Mo-Si-B Coatings Synthesis In Molten Salts And Their Resistance To Oxidation

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Molybdenum as a substrate for the catalytic coatings deposition was chosen due to its high thermal conductivity. Molybdenum oxidation kinetics at temperatures above 350 °C in the presence of oxygen shows a parabolic mass gain which is limited by the diffusion of oxygen through MoO3 at temperatures above 650°C. Electrochemical and diffusion synthesis of protective molybdenum silicides and borides coatings (5-40 μm thick) in molten salts within the temperature range 850-1050℃ were studied. We study the low-temperature oxidation stability of various Mo-Si-B compositions created by currentless silicification of molybdenum sheets in molten salts at 900°C for 7 h to obtain MoSi2 layer followed by borification of MoSi2 phase in ionic melts. The formation of different phases during borification and silicification of molybdenum substrates (MoSi2/Mo) was studied. During currentless borification, MoSi2 phase was transformed into Mo5Si3 phase which became the main one (with content of 10-30 wt.%) after the borification step within the range 750-900℃, and the matrix one (with content of more then 60 wt.%) above 950℃. The MoSi2 phase is always present in coatings the temperature range 800-950℃ after electrochemical synthesis. The main components of the boride phases were MoB2 and MoB5. Pure MoB4 was formed in the volume of the MoSi2 phase after electrochemical borification within the range 760-840°C with a maximum content of 15% by weight at 800°C. Pure MoB was obtained as a matrix phase after currentless borification at 900°C, while pure Mo2B5 is formed in both processes at temperatures above 950°C. The presence of small amounts (12-15 wt.%) of the MoB4 phase formed during MoSi2/Mo coating borification in molten salts significantly improves the oxidative molybdenum bases stability. For the maximum protection improvement, the outer MoSi2 layer was borified without the molybdenum base borification.

Dispersion Kinetics Of High-Temperature Adhesive-Active Metals Nanofilms Deposited Onto Oxide Materials During Annealing In Vacuum

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The use of adhesion-active metals in the form of nanofilms applied to the surface of non-metallic parts is promising, which makes it possible to develop technologies for the production of precision and reliable joints with very thin brazed seams. The aim of this work was to study the dispersion processes of titanium, zirconium, niobium and hafnium nanofilms deposited onto substrates of oxide materials during annealing in vacuum at temperature up to 1600°C. These metals nanofilms 100 nm thickness were sputtered by electron beam onto substrates, which were then annealed in vacuum not worse than 2x10-3 Pa for different times (2-20 min) up to the temperature 1600°C. Annealed films were examined by scanning electron and atomicforce microscopy. It was found that the dispersion of titanium and zirconium films onto oxides proceeds equally: after 10 min annealing at 1400°C the films are almost continuous, but with increasing exposure time to 20 min they already have dispersion process (films cover more than 70% of the substrate surface); the same results were observed in the annealing of films at 1500°C; at 1600°C the they completely disintegrate after 10 min of annealing. When annealing niobium and hafnium nanofilms only after 20 min of annealing at 1400°C there is slight cracking of the films. At 1500°C the films dispersing process is accelerated and after 20 min of annealing the niobium films mostly disintegrated into separate rather large conglomerates and fragments, which covered about 50% of the substrate area, while hafnium nanofilms decayed slower and their fragments after 20 min exposure covered about 80% of the substrates surface. At 1600°C film dispersion intensifies, which leads to their complete disintegration into individual conglomerates. Niobium conglomerates cover only 40–50% of the substrate surface area, hafnium conglomerates – 50–60%.

Ceramic-Spinel Composite Layers As Effective Materials For Protective Interconnector Coatings For Solid Oxide Cells

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High-temperature corrosion of steel interconnects is one of the important challenges to obtain high-performance cells with a very long lifetime in excess of forty thousand hours. The research conducted so far focuses on the well-known manganese-cobalt spinel, which is difficult to recycle and also carcinogenic. In this work, we describe a new material in the form of manganese-iron-copper spinel and its protective, electrochemical, and structural properties. Spinel was synthesized using a modified Pechini method. The thin, reactive element (RE) ceramic layers were applied to the steel plates by an electrolytic technique. On top of the thin RE layers, a thicker Mn-Cu-Fe spinel layer was prepared by electrophoretic deposition (EPD). Thermogravimetric measurements were made by cyclic high temperature oxidation with controlled weight gain. Structural studies were performed using X-ray absorption spectroscopy (XAS) and X-ray diffractometry (XRD) measurements as well as electrical measurements were performed. Additionally, a series of images were taken using a Scanning Electron Microscope (SEM) supplemented by energy-dispersive X-ray (EDX) analyses. The combination of a thin RE layer with a thicker spinel layer is responsible for blocking outward chromium diffusion, reduction of the weight gain of the sample in relation to the sample with the spinel alone, and in relation to the reference samples. In addition, the use of composite layers changes the structural properties of the material itself, as shown by XAS studies and analysis by means of surface and cross-section images made with the SEM and EDS analysis. The use of RE-spinel layers allows for a significant improvement in oxidation properties, and the spinel itself perfectly replaces the commonly used manganese-cobalt spinel. It has been proven that the use of a ceramic layer has a beneficial effect on weight gain, which has an impact on the efficiency of interconnectors and the operation of the entire SOFC system.

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Nano-Tribological Properties Of Annealed Silicon Carbon Nitride Films

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Moving from macro to nanoscale objects causes an increase in the surface area-dependent forces which in turn limits the lifetime and reliability of moving parts of nanodevices. Thus, the investigation and development of the friction and wear reduction elements working at the nanoscale are important. The tribological properties at the nanoscale of plasma-enhanced chemical vapor deposited silicon carbon nitride films deposited at negative substrate biases (Ud) – 5 and – 250 V and annealed at the temperature (Ta) 600, 800, and 1000 °C were investigated by atomic-force microscope in the lateral force mode. The structural and mechanical properties were investigated in [1]. The low-Ud films demonstrated higher friction forces (FF) as compared to high-Ud films. Annealing of the low-Ud films resulted in the gradual reduction of the FF. Whereas the FF of the high-Ud films after annealing at 600 °C was getting lower and increased with the future rising of Ta. The hardness (HK) of the low-Ud films remained almost the same after annealing. Whereas for high-Ud films HK sharply decreased after Ta = 600°C due to lowering of the internal stress and at higher Ta HK was almost unchanged [1]. Thus, the decrease of the FF of high-Ud films at Ta = 600°C similarly could be caused by relieves of the stress. The other changes of the FF in the case of high-Ud and low-Ud films are most probably caused by structural changes. ESR spectra demonstrate an increase in the concentration of sp2 carbon-related bonds with the Ta in both cases [1]. It is a reason to expect that the lowering of FF of the low-Ud films with Ta occurs as a result of increased sp2 carbon. On the other hand, as confirmed by the FTIR and PL spectra [1] the high-Ud films are characterised by low content of nitrogen thus annealing also causes an increasing and predomination of the concentration of Si-C bonds that apparently causes an increase of the friction due to the lowering of the impact of the free carbon phase on the FF.

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Physico-Mechanical Properties Of TiN-TiB2 And TiN-Si3N4 Coatings Obtained By Electrospark Deposition And Laser Treatment

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The electrospark deposition (ESD) process with the use of electrodes made of promising triboceramics TiN–20% TiB2 and TiN–20% Si3N4 followed by laser treatment and the physicomechanical properties of the deposited coatings were studied. The electrode materials based on titanium nitride for ESD were sintered from nanopowder mixtures in a 0.9 kW microwave furnace in the temperature range 1370–1400 °C [1]. Coatings were obtained with an Elitron-24A ESD machine. For all samples, the specific time of deposition was 5 min/cm2. To increase the density and homogeneity of the deposited layers, they were subjected to surface laser treatment (LT) using a Kvant-15 laser pulse-periodic machine.Composite coatings were obtained on a substrate made of steel 45 (carbon structural steel with a carbon content of 0.45%) by electrospark alloying with a pulse energy in the range 0.19–0.75 J. The thickness of the coatings ranges from 30 to 90 μm, and the surface hardness attains 15 GPa.The boron nitride BN (for TiN–TiB2 electrodes) and titanium silicide Ti5Si3 (for TiN–Si3N4 electrodes) were detected in the coatings obtained in individual deposition regimes. After laser treatment, significant changes in the phase composition of coatings were not recorded. The wear resistance and friction force of the obtained samples were determined in tribological tests with the use of a WC–6%Co hard alloy counterbody. According to the test results, the wear of the ESD treated surfaces decreased substantially as compared to the wear of the substrate. In the dynamic test mode, the TiN–Si3N4 coating provides a more than two-fold increase in the wear resistance. Additional laser treatment significantly increased the tribological properties and wear resistance of samples coated with TiN–TiB2. The linear wear of the laser-treated TiN–TiB2 coating under friction against the hard alloy counterbody is 0.5 μm, while the wear of the substrate material (steel 45) is 15 μm. The ESD + LT technique can be used as an efficient method to form protective wear-resistant surface layers based on titanium nitride.

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Preparation Of Electrolytic Refractory Metals Alloys (W, Mo, Re) With Cobalt From Aqueous Solutions.

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The electrochemical method for producing of refractory metals alloys with iron subgroup metals is promising for the aerospace industry and microelectronics, since it makes it possible to obtain coatings on complex-shaped products with a controlled chemical composition, structure and thickness. Such electrolytic coatings make it possible to obtain heat resistance and hardness characteristic of refractory metals, as well as functional properties (magnetic, electrocatalytic and anticorrosive), which significantly expand their areas of application. The electrodeposition of binary alloys CoW, CoMo, and CoRe, and ternary alloys CoMoRe and CoWRe was carried out from two solutions: citrate at pH 3.5 and citrate-pyrophosphate at pH 9.0 at 50°C. The morphology and chemical composition were studied using a scanning electron microscope JED-2300. The work shows the possibility of obtaining high-quality coatings with binary and ternary rhenium alloys from an acidic citrate electrolyte, which contain 44-67 at.% Re (in CoRe), 38-60 at.% Re, 4-10 at.% Mo (in CoMoRe) and 14-41 at.% Re, 4-5 at.% W (in CoWRe) depending on the concentration of potassium perrhenate in the solution (0.01-0.05M) and the deposition current density 5-40 mA•cm-2. Coatings exhibit electrocatalytic properties in the reaction of hydrogen evolution in an alkaline medium and have high corrosion resistance in solutions of various salinity (H2SO4, NaCl, KOH). From the citrate-pyrophosphate electrolyte are deposited binary alloys of composition: CoMo (20-25 at.% Mo), CoW (20-24 at.% W) and CoRe (12-23 at.% Re) and ternary alloy CoWRe (13-45 at.% Re and 3-11 at.% W). Coatings which deposited from this solutions with a high current efficiency (70-80%) and have soft magnetic properties due to the high content of cobalt. Thus, based on the composition of the electrolyte and the modes of electrolysis, it is possible to deposit coatings with the necessary properties.

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LOW-DIMENSIONAL MATERIALS AND NANOSTRUCTURES

Two-Dimensional Carbides, Nitrides And Borides Pave The Road To Future Technologies

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Discovery of new materials provides moments of inspiration and shifts in understanding, shaping the dynamic field of materials science. Following the graphene breakthrough, many other 2D materials emerged. Although many of them remain subjects of purely academic interest, others have jumped into the limelight due to their attractive properties, which have led to practical applications. Among the latter are 2D carbides and nitrides of early transition metals known as MXenes [1]. The family of MXenes has been expanding rapidly since the discovery of Ti_3C_2 in 2011. More than 30 different stoichiometric MXenes have been reported, and the structure and properties of numerous other MXenes have been predicted. Moreover, the availability of solid solutions on M and X sites, multi-element high-entropy MXenes, control of surface terminations, and the discovery of out-of-plane ordered double-M o-MXenes (e.g., Mo_2TiC_2), as well as in-plane ordered i-MAX phases and their i-MXenes offer a potential for producing dozens of new distinct structures. Chalcogen terminated carbides, which are crossover between carbides and chalcogenides, 2D borides, and Si-containing nitrides of transition metals further expanded the family of 2D non-oxide materials in the recent years. This presentation will describe the state of the art in the manufacturing of those new 2D compounds, their delamination into single-layer 2D flakes and assembly into films, fibers and 3D structures [2]. Synthesis-structure-properties relations of MXenes will be addressed on the example of Ti_3C_2. Many MXenes offer high electronic conductivity combined with hydrophilic surfaces. This allows environmentally friendly and scalable manufacturing and processing of MXenes from dispersions in water, with no surfactant of binder added. The versatile chemistry of the MXene family renders their properties tunable for a large variety of energy-related, electronic, optical, biomedical and other applications. In particular, the applications of MXenes in electrochemical energy storage and harvesting, electrocatalytic water splitting and water purification/desalinationare promising. However, MXene antennas, sensors, actuators, films for electromagnetic interference shielding are equally attractive. Structural, tribological and high-temperature applications of MXenes are being explored as well.

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Nanocomposites: Paths to Perfection of Materials

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The report will present the author's vision of the development of materials science of nanostructures. In particular, the multifunctionality of nanomaterials can be achieved mainly through the creation of nanocomposites with a special structure. It is the structure of nanocomposites created as a result of assembly mechanisms acting in Nature that makes it possible to combine structural, optical, photocatalytic, electrical, etc. properties in one material. A variety of such structures of nanocomposites arises due to the connection of nanoparticles by weak chemical bonds that exist between organic molecules, polymersas well as on the surfaces of crystalline particles. The Van-der-Vaal's or hydrogen bonding give lability to the system of nanoparticles with organic molecules and their energy seems to be enough to move small mass crystals in space and assemble into structures. The perfection of such structures is expressed in the achievement of multifunctionality, adaptive stability of the created structures, as well as symmetry and chirality.

Nanomaterials And Engineering To Zero Emission In Renewable Energy

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To make a catalyst active and stable for fuel cell applications, mass spectrometry techniques open the way to understanding in situ behaviour in real electrochemical devices. To achieve the high efficiency of noble metal utilization and theoretical power densities, engineering work must focus on a deep understanding of the structure and optimization of the entire system. The efforts of many scientists are focused on the development of a stable noble free active catalyst for use in fuel cells [1]. But all of them are still far from sufficient stability. Understanding the ultra-low loading activity of a noble catalyst, with sufficient stability in real systems, allows one to obtain an optimal structure with any active catalyst. In our work, mass spectrometry methods were applied to understand the corrosion resistance of an ultra-low pt catalyst obtained by magnetron sputtering. In our work, mass spectrometry methods were applied to understand the corrosion resistance of an ultra-low pt catalyst prepared by magnetron sputtering. Step-by-step optimization of the entire structure of the membrane-electrode assembly made it possible to reach high specific powers. The results and methods obtained will be successfully applied in the development of noble-free materials for fuel cells applications [2].

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Bonds Polarity Effect On Small Boron Clusters Size And Stability

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Borophenes and other 2D boron-rich materials are of current academic and practical interests because of their widely variable interatomic bonding mechanism and related unique complex of physical-chemical properties useful in various technological applications (see e.g. [1,2]). At the lower number of atoms, the all-boron clusters prefer (quasi)planar shapes and then can serve for building blocks for 2D boron materials. Recently, in the frames of phenomenological diatomic molecular model [3] imagining the clusters as certain constructions of pair interatomic chemical bonds, it has been estimated [4] the specific (i.e. per atom or molar) binding energies of small all-boron planar clusters (containing up to15 atoms) in neutral, single-anionic and single-cationic charge states. As cluster is a finite structure of atoms, the static electrical charges localized on the pair of nearest-neighboring atoms differ from those of pairs placed at its center and periphery. There is theoretically analyzed the bonds polarity effect on small boron clusters molar binding energies and, consequently, their equilibrium sizes and relative stability. Non-monotonic dependencies on the number of atoms obtained for most symmetric species should be related with differences in their structures. This result provokes reconsidering assumption that equilibrium structure of a cluster corresponds to its highest symmetry even at the significant polarity of bonding.

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Conditions For The Formation Of A Deposit During Plasma-Chemical Electric Arc Synthesis Of Carbon Nanostructures In A Liquid Medium

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The purpose of this work is to develop and create a scheme of synthesis conditions and deposit formation during the synthesis of nanostructures by the plasma-chemical method in the liquid phase. To date, the conditions for the plasma-chemical synthesis of carbon nanostructures (CNS) is the most common. All over the world, plasma-chemical synthesis is carried out in an electric arc discharge in an inert gaseous environment (ADG), where an inert gaseous environment does not affect the chemical processes taking place in the synthesis zone. The installation of electric arc synthesis in a liquid makes it possible to obtain CNS in dielectric liquid media, where the liquid medium can influence the CNS formation process, both by its chemical composition and temperature (cryogenic liquid media). In work: ● For the first time, a scheme of conditions for synthesis and formation of a deposit was developed and created during the synthesis of nanostructures by the arc method in the liquid phase; ● A model of sputtering and evaporation of the anode electrode, as well as the formation of a deposit in the liquid phase during an arc discharge; ● The technologies for the synthesis of carbon nanostructures in the liquid phase according to the proposed scheme were analyzed; ● It is shown that in the process of electric arc synthesis in a liquid medium with an electrode gap of more than 1 mm, it solves the problem of the formation of a by-product in the form of a deposit on the cathode; ● Studied deposit formation by the method of electric arc synthesis in the liquid phase; ● Studies and results of X-ray phase study of Co-W and Co-Ni nanoproducts (deposits) synthesized by the plasma-chemical method were carried out. The deposit can be considered as a high temperature resistant composite, since the deposit is formed at 12000 K.

Influence Of A Magnetic Field On Morphology And Structural Characteristics Of Granulated Thin-Film Alloys Based On Ag And Co

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Magnetic thin-film systems have found application in spintronics, biotechnology, and medicine [1]. However, when the spin current passes through nanoelectronic elements, a high-gradient magnetic field arises due to very low size of these elements. Such field can lead to noticeable changes in structure of the electronic devices elementary items. It is also known [2] that magnetic fields affect on mechanical characteristics of various materials, such as tensile strength and yield stress, stress relaxation and others. Thin-film alloys Co-Ag were deposited at room temperature in vacuum by electron beam co-evaporation using two independent electron guns. By means of atomic force microscopy the effect of an external magnetic field on the mechanical and structural characteristics of the surface of samples of granular thin-film alloys based on Co and Ag was investigated and analyzed. It was found that even at a relatively low intensity, the first application of a magnetic field has the most significant effect on the sample surface morphology change. The results of the effect of a magnetic field on the thin-film alloy based on Co and Ag with a cobalt concentration of 39 at.% sample surface showed that after the first application of a magnetic field with a magnitude of H = 0.01 T, the values of the structural characteristics of the film surface decreased: the arithmetic mean roughness of the film surface Ra decreased by 19 %, the mean square roughness Rq by 16%, the structural entropy S by 4.5%, and the height of the highest peak by a factor of 4. The escalation in the magnitude of magnetic field to H = 0.1 T and further relaxation in the absence of a field did not significantly affect on the structural characteristics of the film surface in comparison with the values obtained after the first application of an external magnetic field. Under the influence of a magnetic field, the film system passes into a new state. This state differs in its properties from the initial one.

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Localized Nonlinear Spin Waves In Five-Layer Magnetic Structures With Metasurfaces

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Multilayer magnetic structures are widely investigated regarding their potential technological applications. Recently, magnetic film micro- and nanostructures have been intensively studied as possible candidates for the creation of promising devices for spintronics and magnonics. Magnonics deals with the propagation of spin waves in magnonic crystals – artificially created periodic structures based on magnetic and, possibly, non-magnetic materials. Of particular interest are multilayer periodic structures with magnetic ordering which have pronounced anisotropic properties. In turn, the presence of metasurfaces (thin layers) in layered structures with different magnetic properties and different ratios of layer thicknesses is the requirement for the formation of spin-wave excitations localized at the metasurfaces between the contacting magnetic layers [1]. Earlier, the analysis of such excitations was limited to linear on the oscillation amplitude approximation, but now the study of nonlinear spin-wave excitations and their properties become actual. Due to the new technological possibilities of the creating of periodic nanostructures, the investigations of the propagation of nonlinear spin waves localized near thin layers of the magnetic material in a system of thin plane parallel magnetic layers (plane magnetic defects) are of great practical interest. In the present work, we study analytically the localization of nonlinear waves propagating in a five-layer magnetic structure along the alternating wide and thin layers with different single-ion anisotropies in them. We find the exact solutions for spin wave localized states, the total number of elementary excitations localized in the system and its total energy as functions of the scaling variable characterizing the distance between the plane magnetic defects. We present all these dependences in the universal scaling forms valid for different values of the characteristic of magnetic defects.

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Effect Of Pt Alloying On Phase Transformations In Nanoscale Ni(Pt) Films

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NiSi is the most suitable low resistance material (~ 10 μΩ•cm) for the formation of contacts and interconnects in microelectronics during the transition to 22 nm CMOS nanotechnology. It is necessary to increase its thermal stability and prevent the transition of this phase at temperatures above 750 ℃ into high-resistance NiSi2 (~ 35 μΩ•cm). The aim was to study the effect of Pt doping of nanoscale Ni(Pt) films on the processes of phase formation and thermal stability of NiSi silicide during annealing in a vacuum. Nanoscale Ni(Pt) films by the thickness of 30 nm were obtained by magnetron sputtering onto Si(001) substrate. The films were annealed in a vacuum at temperatures of (450-1000)℃ for 30 s. Phase formation processes in Ni(1 at.% Pt) and Ni(8 at.% Pt) films were studied by X-ray diffraction, Rutherford backscattering spectrometry, SNMS and resistometry. The thermal stresses that appeared in the films after deposition and annealing were evaluated. It was established that during thermally activated processes the silicide phases formation in Ni(Pt) films differs from phase equilibrium diagrams and occurs in other temperature ranges. NiSi in (Ni + 1 at.% Pt) and (Ni + 8at.%Pt) films is formed during annealing at 450 ℃ and 500 ℃, respectively. Annealing temperature rise lead to increasing in the level of compressive thermal stresses in the NiSi layer. An increase in the level of tensile mechanical stresses in a film with a higher Pt(8 at.%) lead to rise in the temperature of NiSi formation compared to the Ni(30 nm) film. NiSi remains stable up to 900 ℃ which is 150 ℃ higher than in the Ni film. Increasing Pt concentration leads to the formation of a Ni(Pt)Si solid solution due to the unlimited NiSi and PtS solubility. The increase in the NiSi thermal stability is associated with a significant decrease in the driving force of the NiSi into NiSi2 phase transition due to the lower $|\Delta G|$ free energy of the solid solution.

Electrochemical And Capillary Properties Of 2D $ReSe_2$ Nanosheets

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Rhenium diselenide ($ReSe_2$), as a two-dimensional (2D) material of layered transition metal dichalcogenide, renders with wide applications in (opto-)electronics, such as photodetectors and field effect transistors, and electrocatalyst for the hydrogen evolution reaction. According to X-ray studies, X-ray photoelectron spectroscopy and Raman spectroscopy $ReSe_2$ nanosheets are homogeneous (sizes about 20 nm). The samples of $ReSe_2$ nanosheets films were prepared on glass / quartz substrates after preliminary ultrasonic treatment in aqueous alcohol solutions. For the first time, studies of the processes of wetting of $ReSe_2$ nanosheets with water were carried out. The sessile drop method was used to determine the degree of wetting. It is shown that under normal conditions $ReSe_2$ nanosheets are wetted by water. The contact angles are less than 90 degrees, which indicates a tendency for the surface of $ReSe_2$ nanosheets to be hydrophilic. The results of electrochemical studies of $ReSe_2$ nanosheets films in aqueous solutions (3% $NaCl/H_2O$) are presented as well. Electrochemical corrosion measurements were performed by potentiodynamic polarization curves method. Platinum was used as the auxiliary electrode; potentials (anode or cathode) applied to the work surface which were determined by AgCl reference electrode. It was shown that $ReSe_2$ nanosheets films (after ultrasonic treatment of the starting powder in aqueous solutions of ethyl alcohol) during subsequent contact with air interact of surface nanosheets with oxygen (air) which probably leads to the formation of nanoheterostructures ReO_3–$ReSe_2$. These factors change the corresponding polarization anode and cathode curves and enhancing of water wetting. $ReSe_2$ nanosheets, as well as possible nanoheterostructures ReO_3–$ReSe_2$ are chemically stable in electrochemical processing. $ReSe_2$ nanosheets and nanoheterostructure ReO_3–$ReSe_2$ are promising for future studying of anticorrosive characteristics of coatings with their participation.

Obtaining Of Max Phases By Mechanically Activated Self-Propagating Synthesis For Their Use As MXenes Precursors

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MXenes or two-dimensional (2D) transition metal carbides similarly to graphene are finding their way to a wide variety of applications [1]. The utilization of MXenes is promising for energy storage, electromagnetic interference shielding, for development of gas sensors, electrocatalysis and many other uses. MXenes can be obtained by the selective etching of A-element layers from the MAX phases. The treatment, which occurs in hydrofluoric acid, results in a particular layered structure of MXene nanosheets. MAX phases with the general formula Mn+1AXn (M is a transition metal; A is an element from groups IIIA and IVA as well as P, Si, As, Cd; X is C and/or N) combine the properties of metals and ceramics [2]. Synthesis of MAX phases is carried out mainly by methods of hot isostatic pressing, spark plasma sintering and by the method of self-propagating high-temperature synthesis (SHS). These processes are quite complex and non-technological, while in order to obtain MXenes it is desirable to synthesize MAX phases in the form of a dispersed powder to improve metal etching. The aim of this work is to obtain the Cr2AlC, Ti2AlC and Ti3SiC2 MAX phases in the nanodispersed state using high-energy milling of the initial components in a planetary mill. In the present investigation the milling of reactants was performed in argon atmosphere in a planetary mill AIR-015M. The phase composition of the samples was examined by XRD using a diffractometer “DRON 3” (Cu Kα radiation). Single-phase MAX phases Cr2AlC and Ti2AlC in the highly dispersed state were obtained using ball milling of 2Cr+A+C and Ti+TiH2+Al+C powders in a planetary mill with subsequent heat treatment of mechanically activated mixture in the temperature range 800–1150 °C. Specific surface area of synthesized powder phases is 3 m2/g. It is shown that in the 2T–Al–C and 3Ti–Si–2C systems MAX phases Ti2AlC and Ti3SiC2 can be formed as a result of the reaction of mechanically activated self-propagating synthesis.

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Obtaining And Diagnostics Of Thin Films Of Amorphous Carbon On A Glass Substrate

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A technology is developed for producing nanomaterials with a photoinduced structure comprised of thin films of amorphous carbon with a copper sublayer on a glass substrate [1,2]. The films were deposited in a single cycle using thermal evaporation of graphite rods in a vacuum and a system for filtering off microparticles in the evaporated material. The composition, structure, and morphology of thin (a-C) films on a glass substrate and on a copper sublayer were investigated using the methods of Raman and adsorption spectroscopy [3,4]. Based on the analysis of the composite (a-C:Cu) spectra, it is found out that this composite has an amorphous-like matrix with a structure determined by the thin copper layer. Nonthermal changes in the color, size, and shape in the exposure spot on the (a-C:Cu) were observed under exposure to light. This effect can be explained by the π-electron resonance interactions in the (a-C:Cu) composite, and possible increase in the phonon mean free path. A technique for obtaining wide-angle X-ray scattering profiles of grazing incidence X-ray diffraction is improved and implemented. This technique provides sample opportunities for analyzing the features of the short-range ordering in both ultra-thin AMSs and inorganic films with an accuracy sufficient for the diagnostics of the state of short-range ordering.

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Precursor Pore Structure Evolution During Production Of Nanopowders With Perovskite Type Structure In La_2O_3 -Lu_2O_3-Yb_2O_3 System

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The development of technologies for transparent ceramics production requires starting materials with defined properties. The precursor was synthesized by heterogeneous precipitation of a mixture of solutions of La3+ and Lu3+ rare-earth nitrates with 3 vol. % Yb3+ luminescent additive at Ln3+ nitrate concentration of 0.1 mol/l, and solution temperature of 80°C. A 1 M ammonia solution containing 5 vol. % urea was used as a precipitant. The precipitate was separated by triple centrifugation from distilled water. Intermediate samples were obtained by annealing at a heating rate of 5 deg/min. The adsorption-structural studies characterize samples as mesoporous nanodisperse bodies. The dependence of the total porosity characteristics on the temperature has a non-monotonic falling character up to 700°C. With further increase in temperature up to 825°C the value of total pore and mesopore volumes increase significantly with a slight decrease in surface area. The precursor (Sbet=37 m2/g) is characterised by a bimodal distribution of mesopore volumes and surfaces is preserved up to 700°C. The values of the major average equivalent diameters between 4.65 and 8.7 nm gradually increase to 6 and 10.7 nm, respectively. At the same time the type of H2 hysteresis loops on the sample isotherms practically does not change, which corresponds to the corpuscular structure. With an increase in temperature above 750°C the structure of the samples changes into homogeneously packed agglomerates or globule pellets of the same size, as evidenced by the change in the hysteresis loop type on H1. Differential size distributions of mesopore volumes and surfaces become unimodal with average equivalent mesopore diameters of 17-18 nm. The specific surface area of the obtained powder is 18 m2/h. Corresponding to the particle size of 40 nm. Thus, the precursor temperature decomposition takes place up to 750°C, and the further heating contributes to the formation and accumulation of the final product.

Aerogel Materials For Capacitive Electrodes In Supercapacitors

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Energy storage is one of the most important topics of the scientific research today. Supercapacitors (SCs) are the most promising candidates in comparison to batteries and fuel cells due to their relatively simple structures and inherent electrochemical properties. High-performance SCs need to show high energy and power density, fast charge-discharge and long cycle life. Investigation of flexible electrodes with high capacitance and high electrical conductivity ensures fast charge-discharge. Graphene that has large specific surface area and high electrical conductivity is a promising material for the energy storage. In the current work, composite electrodes based on reduced graphene oxide (rGO) aerogel were used for the fabrication and further analysis of symmetric SCs. Moreover, due to the development of flexible energy storage devices with high performance for next-generation wearable and flexible electronics, the textile substrate (carbon cloth) was used in the current work. Prepared rGO-aerogel-based electrodes were found to be chemically stable after long cycling test (after 10 000 charge/discharge cycles) in Na2SO4 electrolyte. Calculated gravimetric capacitance strongly depended on processing details such as annealing temperature, wettability of materials and others. The highest specific capacitance value of 129 F g-1 was obtained for the electrode on the carbon cloth with rGO aerogel annealed at 180 °C that was much higher than that for electrodes with rGO aerogel annealed at 700 °C. The initial supercapacitor power density increased in almost 10 times from 61 to 602 W kg-1 when the current rose from 0.1 to 1 A g-1. During the long-term durability test, SC energy density decreased from 4.2 to 2.7 Wh kg-1 while the power density was reduced from 61 to 53 W kg-1. Further study of structure-properties relationship is planned.

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Creation Of A New Type Of Antifrictional Composition Coatings From Ferrocene-Containing Polymers And Titanium Oxide Nanoparticles

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Improving the reliability and durability of tribotechnical units of equipment operating under conditions of significant dynamic loads, abrasive wear, corrosion, temperature changes, is becoming increasingly important. The main ways is to create new tribotechnical materials and provide realization of the phenomenon of frictional transfer and film formation. The transition to dry friction pairs has not alternative. The polymer composites and coatings with self-lubricating properties are used. Samples of composite materials based on polyimides (PI) with ferrocene-containing fragments and reinforcing fillers TiO2 nanoparticles were made. They were applied to a metal surface to study tribological properties. The tribological behavior of ternary nanocomposites under dry conditions was evaluated: their friction coefficients μ and wear rate W for composite materials based on polymers with/without ferrocene fragments and the addition of TiO2 nanoparticles were investigated. μ PI without ferrocene was 0.42, and with the ferrocene addition was 0.35. That is, the tribological behavior of PI is improved by the introduction of “non-rigid” fragments. The introduction of 4% TiO2 reduces μ of the mixture by 34%. Nanoparticles perform two main functions: they promote crystallization and act as crack deflectors. For ferrocenes, μ drops from 0.32 for polyimide to 0.21 for nanocomposite with 4% TiO2. For all samples, μ is less when using ferrocene derivatives, which is associated with energy scattering fragments. W PI decreases with the addition of ferrocene. Addition of TiO2 some more reduces the property. A new type of antifriction composites and self-lubrication coatings has been developed by creating polymeric binders with high wear resistance due to rigid structural fragments of the ladder type, and high antifriction properties and high ability to non-destructive scattering of excess energy in the contact zone due to structural with high intensity of rotational molecular movements.

Development Of Polymeric Coatings With The Effect Of Self-Lubrication Based On Polyimides Containing Graphene Oxide

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There is a need for antifriction products that can work reliably at high sliding speeds. Self-lubricating polymer composite coatings with adjustable tribological and mechanical properties are used to reduce friction and wear. The addition of functional fillers extends the life of coatings, providing a combination of low friction, high wear resistance, high load resistance, high heat resistance and high adhesion. The product of graphene oxide (GO) with grafted polyamide acids (PI/OG) was obtained. The resulting product was treated with a metal plate followed by heat treatment. The produced films had a thickness of 100–210 μm. The tribological characteristics of PI/GO composites with different GO contents were investigated - the coefficient of friction μ and the wear rate W were determined. The thickness of the transferred film of the PI/GO composite increases with the addition of GO and its adhesion to the counterbody increases, which contributes to the improvement of tribological characteristics. It is found that the coefficient of friction of PI/GO composites decreased with the addition of 1 to 5% GO. At the composite PI/3%GO compared to pure PI μ is changed on 26%. PI/GO composites also show a tendency to wear rate reduces during dry sliding on the steel counterbody, to a GO content of less than 3%; then the wear rate increases with increasing GO content. The change in the wear rate of the PI/3%GO composite is 21%. The additions of 3%GO to PI improved the tribological properties: the lowest friction coefficient and wear rate. It can be a promising tribomaterial for dry sliding conditions. This improved tribological behavior of polymeric composite materials is shown to be associated with the transferred films formation, and the wear reduction is due to the redistribution of load provided by the reinforcement components

Morphology And Optical Properties Of ZnO Nanostructures Obtained On Different Types Of Si Substrates By APMOCVD Method

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The potential applications of ZnO nanostructures (NS) and respective device fabrication determines the surface morphology of the films. The type of substrate significantly influences the microstructure and morphology of the ZnO films. Particularly, developed surface texture is required to provide light scattering subsequent light trapping inside the silicon structure that important for further improvement in optoelectronic devices. Thus, it is necessary to investigate the substrate effect on structural and optical properties of ZnO NS. ZnO NS obtained by atmospheric pressure metal-organic chemical vapor deposition method using Zinc Acetylacetonate powder as precursor. As substrates were used different type of polished and unpolished silicon (Si) with crystallographic orientation (100) n and p-type of conductivity. The structure of grown ZnO NS was characterized by X-ray diffraction analysis, scanning electron microscopy and Raman scattering. Optical properties are characterized by means of photoluminescence (PL). ZnO NSs demonstrate the microstructure, peculiar for deposited films – dense coverage of not hexagonally faceted granular structure, which is probably due low growth temperature. The dimensions of grains changes with type of Si substrate and increases from 50-110 nm in the case of polished n-Si to 100-250 nm on polished p-Si substrates. Two Raman peaks at about 100 and 437 cm-1 related to the low-frequency E2 mode is associated with the vibration of the heavy Zn sublattice, and the high-frequency E2 mode involves only the oxygen atoms, respectively are detected in all ZnO NS. The weak feature at 334 cm-1 is related to the second-order E2high-E2low band of ZnO. The presence of peaks at 380 and 410 cm-1 corresponding to A1TO and E1TO modes indicates that ZnO NS have not grown preferably c-axis perpendicular to the substrate. The influence of Si substrate type on PL of ZnO NSs will be presented and discusses in our report in detail.